SURGERY

GYNECOLOGY AND OBSTETRICS

An International Magazine, Published Monthly

VOLUME 76 JUNE, 1943 NUMBER 6

THE SURGICAL MANAGEMENT OF SOME OF THE MORE COMPLICATED PROBLEMS OF PEPTIC ULCER

FRANK H. LAHEY, M.D., F.A.C.S., and SAMUEL F. MARSHALL, M.D., F.A.C.S.,
Boston, Massachusetts

IN the last few years the surgical management of a chronic callous ulcer of the stomach and duodenum which fails to respond to conservative treatment has been established on a sound and quite universally accepted basis. Out of a confusion of conflicting opinions, definite indications for surgery have been outlined repeatedly and accepted by the majority of the medical profession. The need for adequate subtotal resection of the stomach for most chronic intractable ulcers is generally conceded. Furthermore, it is conceded that the likelihood of recurrent ulcer distress is reduced to a reasonable minimum by this operation and that recurrent ulcer, while it may occur, is infrequent after a properly executed resection of the stomach.

In this paper, our interest is not in these now recognized generalizations but in some of the more troublesome and complicated problems which arise in gastric and duodenal surgery as well as some of the conditions which follow a previous conservative or radical surgical procedure. In this complicated type of case the surgeon's experience and judgment may be taxed to the utmost, and he is apt to be faced with conditions producing the highest mortality rates in gastric surgery. He must acquire not only considerable technical experience with gastric surgery but he must also develop experienced surgical judgment with cases of this type if he wishes to avoid serious fatality percentages.

Since we have standardized the procedure at the Lahey Clinic, the risk accompanying resection of the stomach for the average duodenal, gastrojejunal, or gastric ulcer exclusive of gastrojejunocolic fistula is now reduced to 2.7 per cent. However, one cannot assume an attitude of complacency toward fatalities in this technically difficult group of cases, and so we have been interested in developing methods of surgical approach which will retain the risk at a minimum level.

The Clinic has had under hospital management 7,000 peptic ulcer cases, of which 6,550 were duodenal ulcers and 450 were gastric ulcers. Of this group of 7,000 peptic ulcer cases, 18.1 per cent of the gastric ulcer cases and 6.59 per cent of the duodenal ulcer cases required surgery for the relief of symptoms.

This paper deals with the complications in the last 251 consecutive patients who had subtotal gastric resection for peptic ulcer of various types. It includes subtotal gastrectomy for 152 duodenal ulcers, 45 gastric ulcers, and 46 jejunal ulcers in which were 8 gastrojejunocolic fistulas. There were 8 postoperative deaths, an operative mortality of

From the Department of Surgery, The Lahey Clinic, Boston.

3.2 per cent, which includes the mortality of gastrojejunocolic fistula. Of these, 5 were patients with primary duodenal ulcer, 2 were patients with gastrojejunocolic fistula, and 1 a patient with a recurrent ulcer after subtotal gastrectomy.

The ulcer states which have been complicated and difficult to manage are the low duodenal ulcer involving the common bile duct in its indurated scar, the ulcer located at or below the entrance of the common duct in the duodenum, the gastrojejunal ulcer, the gastrojejunocolic fistula, and the recurrent ulcer in the gastric stump after a high subtotal gastrectomy. All the deaths among the 251 patients subjected to total or subtotal gastrectomy for ulcer, with the exception of 1 patient who died of embolus, occurred in patients having ulcers of these complicated types. Two were patients with duodenal ulcer involving the common duct, 2 were patients with an ulcer below the level of the point of entrance of the common duct into the duodenum, 2 were patients with a gastrojejunocolic fistula, and 1 a patient with a large recurrent ulcer in a gastric stump, the ulcer being of such size as to occupy practically the entire gastric stump and to require total gastrectomy.

In the surgical treatment of a patient with a duodenal ulcer for whom subtotal gastrectomy is contemplated, the first objective should be to expose the common duct and to settle its relationship to the level of the ulcer in the duodenum. To select the correct type of operation, one must first decide whether, after removal of the ulcer with that part of the duodenum which it involves, a sufficient amount of duodenum will remain above the sphincter of Oddi to permit safe inversion of the duodenal stump without obstruction of the entering bile duct. We have occasionally found a duodenal ulcer so low that after removal of the involved portion of duodenum, unless some measure was instituted to prevent it, safe inversion of the cut end of the duodenum would occlude the entering bile ducts (Fig. 1, a). In such cases it is advisable to open the common duct low and to insert a T tube with one long limb passing through the sphincter (Fig. 1, b). This not only keeps the bile sphincter open until the duodenal stump heals and prevents jaundice from pressure of the inverted duodenal stump on the entering common duct (Fig. 1, c), but also makes it possible to be sure of the relation of the retroduodenal portion of the duct to the ulcer.

If the duodenal ulcer is actually below the level of the papilla of Vater, as in 1 patient in whom death occurred after an unwise decision by one of us (F. H. L.) to employ subtotal gastrectomy, excision of the ulcer with the involved portion of the duodenum should not be undertaken but rather a gastroenterostomy or a Finsterer resection by exclusion (Fig. 2).

If the duodenal ulcer is close to or in contact with the common duct, it is here that the most experienced judgment is necessary (Fig. 3). In a written discussion a differentiation between a removable ulcer of this type and one which should not be removed is difficult. The distinction is clear to those who have dealt with a considerable number of duodenal ulcers, but it is not easy to make for those who are relatively inexperienced with these cases.

One sees two types of duodenal ulcer adherent to the common duct, that type which consists largely of dense but flexible and movable scar tissue and that type which consists of a mass of firm, inflexible, white scar tissue of thick consistency and light in color. Removal of the latter gristle-like type of ulcer, whether or not it invades the common duct, should usually not be undertaken as it frequently cannot be done safely. Ulcer exudate of this latter type is of such cartilage-like consistency that it cannot be separated anatomically from the duct or other adjacent anatomical structures, and in addition, in its separation one can so tear up the pancreas as to make possible a complication which can produce a fatality—pancreatitis. In the other type in which the flexible scar and adhesions about the ulcer have occluded the duct, removal can be undertaken safely.

The natural downward approach to the duct in separating the common duct from the scar and exudate of the ulcerated duodenum from the ulcer is not the best one. If one attempts to separate the duct from the ulcerated duodenum from above downward through the scar, it is difficult not to make an opening into the duodenum and thus destroy

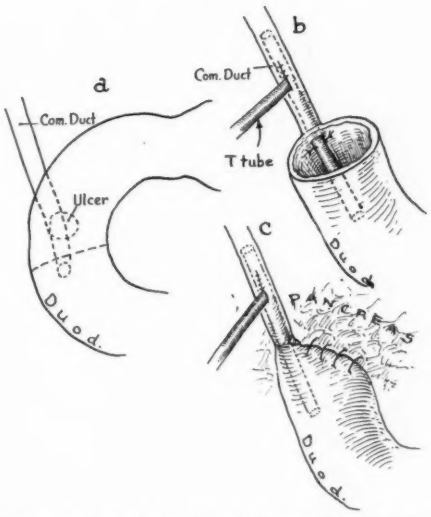


Fig. 1. a, The relationship of a posterior wall ulcer adherent to the common duct and close to the point where that duct enters the duodenum. As indicated by the transverse dotted line, the ulcer is so close to the point of entry of the common duct that it may be necessary to transect the duodenum at a dangerously low level in order to get the ulcer out. b, The close relationship of the sphincter to the cut edge of the duodenum when it is necessary to transect the duodenum low as in a. A method of decompressing the common duct by inserting a T tube with its distal end projecting into the duodenum. c, The closed end of the duodenum with the T tube in the common duct projecting into the duodenum is of value in preventing obstruction of the duct while the inverted end of the duodenum is healing.

part of that structure which is so much needed for safe inversion, or one may tear directly into the bile duct, a casualty in duct destruction which sometimes cannot be repaired satisfactorily. In such low ulcers adherent to the duct, mobilization of the duodenum below the point where the duct passes behind it and turning the duodenum inward and upward exposes the retroduodenal duct where it is not caught in the ulcer scar, and dissection of the duodenum upward from the exposed duct may be accomplished not only with protection of both these structures but often frees a surprising amount of duodenum proving valuable in the safe inversion of the duodenal stump (Fig. 4).

To summarize our experiences with ulcers of this type, we advocate the insertion of a long-limbed T tube into the common duct and through the sphincter in the removal of

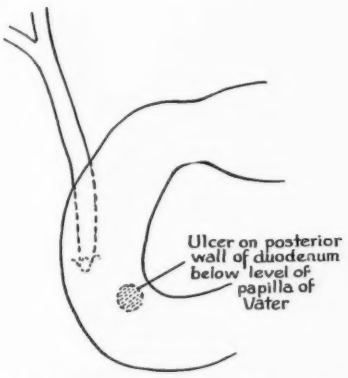


Fig. 2. The location of the ulcer in 2 cases in which it was actually below the level of the point where the common duct entered the duodenum.

certain low lying duodenal ulcers. There are certain gristly types of exudate in low duodenal ulcers involving the bile duct in which subtotal gastrectomy with removal of the ulcer is unsafe and contraindicated. The safest way to separate a low duodenal ulcer which has involved the common duct is by mobilizing the duodenum below the duct, thus approaching the duct outside the ulcer scar through an established retroduodenal line of cleavage.

The next problem which we wish to discuss is that of gastrojejunal ulcer following gastroenterostomy. Although its true incidence is unknown, it is high, perhaps over 15 per cent. It is more apt to occur in young people with high acids and is more intractable to nonoperative management than a primary ulcer in the duodenum or stomach. It can occur very early or very late after anastomosis of the stomach to the jejunum. We have had one occur 7 weeks after operation and several 15 to 20 and even 27 years after operation. However, we have successfully treated patients with gastrojejunal ulcer medically, and we have observed the healed scars of gastrojejunal ulcers in gastroenterostomy stomas at operation for other lesions. We believe the occasional spontaneous closure of a gastroenterostomy stoma is often due to the scarring secondary to a healing gastrojejunal ulcer.

We have performed 46 operations for gastrojejunal ulcer in patients who had had a

Fig. 3. It is difficult to illustrate a cartilage-like duodenal ulcer involving the common duct. The artist, however, has attempted to portray the difficulty which would arise in trying to separate such an ulcer and involved duodenum from the common duct.

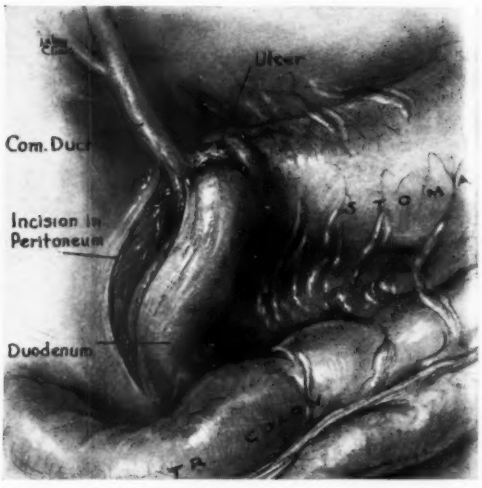


Fig. 4. Note the incision of the parietal peritoneum beside the duodenum, the duodenum rolled inward, and the common duct mobilized. By this plan the common duct can be separated from the ulcer and its adhesions much more readily than if approached from above.

Fig. 5. The arrow shows a gastrojejunal ulcer already adherent to the transverse colon. Immediate surgery was and should be undertaken before it is possible for perforation into the transverse colon to take place, with the result that a gastrojejunocolic fistula is created.

gastroenterostomy. There was 1 death. If there is any ulcer state in which the low gastric acids or anacidity so frequently occurring after high subtotal gastrectomy is essential, it is in the cases of gastrojejunal ulcer. In this group, high postoperative acidity, which has a tendency to produce recurrent ulcer, has usually been demonstrated. In such cases extremely radical and high subtotal gastrectomy is particularly necessary to produce postoperative anacidity or acidity below 10.

One type of gastrojejunal ulcer for which we believe immediate subtotal gastrectomy should be undertaken is the gastrojejunal ulcer adherent to the transverse colon (Fig. 5). This is the stage of gastrojejunal ulcer preceding erosion into the transverse colon and production of a gastrojejunocolic fistula, and in such cases operation should be undertaken before the ulcer perforates into the colon and produces a more dangerous and complicated technical problem. On operation in the case illustrated in Figure 5, the ulcer had already eroded through the muscularis, but the mucosa was still intact permitting separation without perforation and contamination of the contents of the colon.

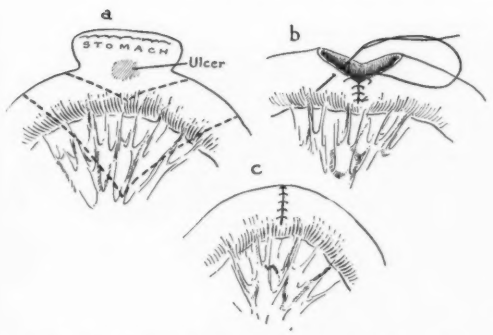


Fig. 6. The method previously published (F. H. L.) by which a gastrojejunal ulcer may be removed without completely transecting the jejunum. Note that closure of such an opening into the jejunum leaves the caliber greater than it was originally. Such a partial resection of the jejunum has less tendency to produce temporary obstruction and closure is simpler than with complete transection and complete end-to-end anastomosis.

Little need be said about the now quite standardized procedure of subtotal gastrectomy for this lesion except to call attention to two technical procedures which have proved valuable to us.

Sometime ago one of us (F. H. L.) described a method of taking down a gastroenterostomy without completely cutting across the jejunum, thus requiring a complete end-to-end anastomosis (Fig. 6). In this procedure only a fraction of the entire caliber of the jejunal wall is removed and the mesentery remains intact. This plan permits safe reunion of the bowel wall edges without dealing with the mesenteric border of the jejunum, and so reestablishes the caliber of the jejunum that it is larger than it was originally.

In separating the proximal and distal loops of a gastroenterostomy in subtotal gastrectomy for gastrojejunal ulcer, particularly of the so called no-loop variety, the proximal jejunal stump of the gastroenterostomy may be found to be very short. One of us (F. H. L.) has described a method of transposing a short proximal jejunal stump under the vascular mesenteric root by incising the parietal peritoneum about the ligament of Treitz and closing the cut end of the proximal loop of jejunum, tucking it under the vascular mesenteric root, and bringing it out through the parietal peritoneum on the right side for an

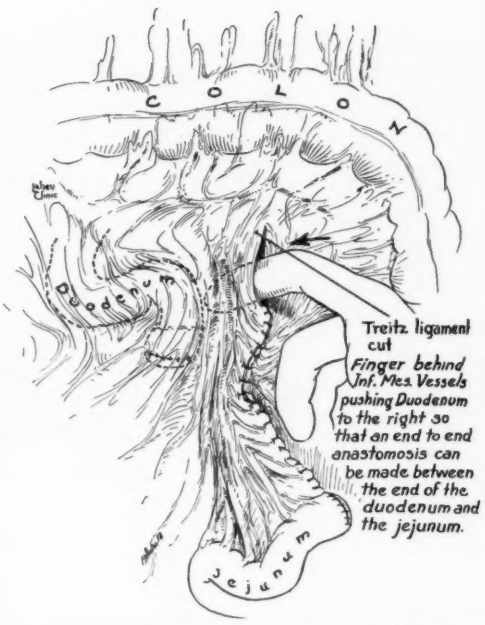

COLON
Duodenum
Jejunum
Treitz ligament cut
Finger behind Inf. Mes. Vessels pushing Duodenum to the right so that an end to end anastomosis can be made between the end of the duodenum and the jejunum.

Fig. 7. The parietal peritoneum has been cut about a short jejunal stump, the end of which has been inverted. The short stump has been pushed beneath the mesenteric vessels where it can be pulled through the right mesenteric peritoneum and anastomosed to the distal end of the jejunum by end-to-end or lateral anastomosis, as preferred.

anastomosis, or turning down the hepatic flexure for antecolic-duodenal-jejunal anastomosis. This has occasionally proved of great value in simplifying the management of gastrojejunal ulcer with a short proximal jejunal loop, and may be particularly valuable after resection of the right and transverse colon in gastrojejunocolic fistula when the jejunal fossa and the short jejunal stump can be so well visualized (Fig. 7).

A gastrojejunocolic fistula is a most serious complication of gastrojejunal ulcer. It presents not only difficult technical problems in its surgical management, but particularly when the fistulous opening into the colon is large, occasions serious constitutional disturbances. Since much of the food in the stomach passes directly through the fistula from the stomach into the colon, weight loss and avitaminosis effects approaching those of pellagra occur. In addition, the escape of

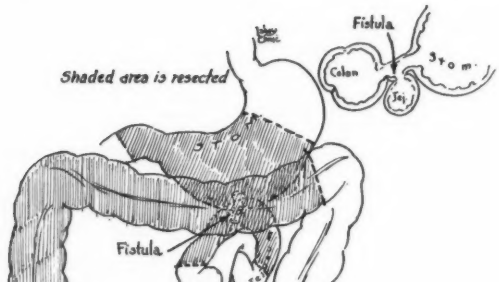


Fig. 8. The first step in the surgical management of gastrojejunocolic fistula. The ileum has been cut off close to the ileocecal valve, the proximal end turned in, and anastomosed laterally to the descending colon. The terminal distal segment of the ileum is to be turned in and dropped back into the abdomen until the second stage of the operation 2 months later. The shaded area represents the block of colon, jejunum, stomach and duodenum to be removed intact at the second stage of the operation. By means of this plan the jejunal ulcer, segment of jejunum involved, and its perforation into the transverse colon are excised without soiling. The subtotal gastrectomy can be done without spilling any of the colon contents. In the right upper corner is shown a fistula connecting the stomach, jejunum and colon, indicating how desirable it is not to open the fistula into the colon.

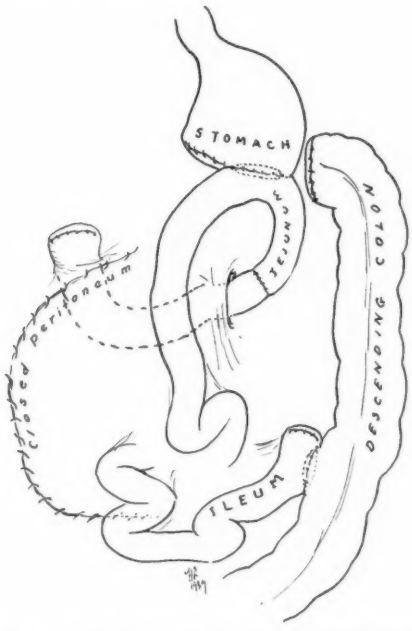


Fig. 9. The two stage operation for gastrojejunocolic fistula has been completed, with removal of the right half of the transverse colon, the ascending colon, the gastrojejunocolic fistula, and resection of the portion of the jejunum which is involved in the ulcer and the stomach. The ileum has been anastomosed to the descending colon as the first stage of the procedure which is to be carried out.

feces into the stomach and with this the belching of skatole has a most depressing effect on appetite. It is not surprising that severe degrees of inanition not infrequently accompany this complication and, up to the time we developed the procedure illustrated here, probably played a considerable part in fatalities. When the gastrojejunocolic fistula is small, it can be satisfactorily managed by separation and closure. When it is large, it is less possible to separate it safely and close the fistula into the colon without dangerous contamination of the peritoneal cavity. Because of this danger the procedure illustrated here was developed by one of us (F. H. L.) and has been used by both of us in a total of 8 cases. One death has occurred and that after the first stage.

As the first step in this two stage method of management of gastrojejunocolic fistula (Figs. 8 and 9), the ileum is divided a short distance from the ileocecal valve, and the ends of the distal and proximal stumps of divided ileum are carefully inverted. The inverted distal end of the ileum is dropped back into the abdomen, and the proximal ileum is anastomosed laterally high to the descending colon. In this way, a good part of the fecal stream is directed into the colon beyond the point of the fistula into the stomach and jejunum. The patient is then sent home for two months, during which time, in our experience, he shows considerable general improvement together with a gain in weight.

At the second operation the ascending colon and short stump of the ileum are mobilized from their position on the posterior abdominal wall by incising the lateral fold of peritoneum and ligating its mesentery. The blood supply

of the transverse colon up to and beyond the gastroenterostomy but proximal to the splenic flexure is ligated and these structures freed from their mesenteric attachments. The transverse colon well to the left of the fistula is closed with the De Petz sewing machine, cut across, and its ends safely inverted. With the transverse colon turned up, the proximal and distal loops of the jejunum leading to the gastroenterostomy are cut between clamps. The stomach is devascularized, the duodenum cut across and inverted, the sewing machine placed high up on the stomach and the structure cut across with the cautery between the double row of clips of the sewing machine. This permits lifting out of the field in one block all the colon up to the splenic flexure with the fistula in it unopened, the section of the jejunum anastomosed to the stomach at the point of the old gastroenterostomy with the gastrojejunal ulcer and fistula onto the colon, the lower two-thirds of the stomach with the gastroenterostomy, the gastrojejunal ulcer, and the fistula into the colon unopened and undisturbed. With this mass of intestine out of the way, the re-establishment of the jejunal canal by lateral or end-to-end anastomosis is much simplified since it is now so clearly visualized. If the resulting proximal jejunal stump is unduly short, it may be freed from the parietal peritoneum above the ligament of Treitz, as described above (Fig. 7), pushed beneath the mesenteric root, and the anastomosis completed in front of the mesenteric root. With the anastomosis of the jejunum complete the typical Hofmeister anastomosis of the jejunum to the gastric stump may be completed in an open and unhampered field.

To those inexperienced with this type of gastric surgery, this may seem an operative undertaking of forbidding magnitude. Perhaps our experience with colonic, gastric, and jejunal resections causes us to minimize its magnitude, but we do not think so. We believe that the removal in one piece of the ascending colon, the right half of the transverse colon, and the jejunum and stomach, with the contained and unopened ulcer and fistula, not only adds to the safety of the operation from the point of view of contamination, but actually by providing better exposure and approach to the jejunum and stomach for re-establishment of the streams, adds to the ease and speed with which the operation can be done, particularly when the fecal stream has previously been established and is functioning beyond the level of that portion of the colon being dealt with.

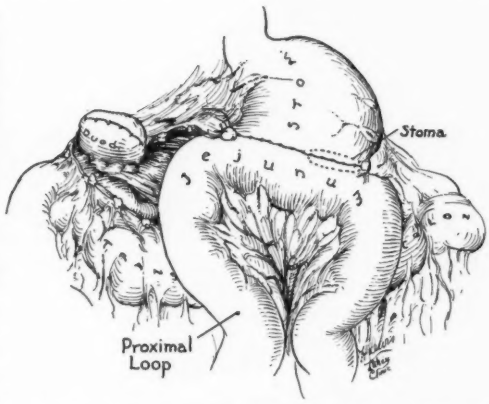


Fig. 10. The long antecolic loops and the antecolic position of the gastric stump in antecolic anastomosis in subtotal gastrectomy for ulcer. This drawing shows the ease with which recurrent gastrojejunal ulcer after subtotal gastrectomy can be managed with this type of antecolic anastomosis. Note the antecolic position of the gastric stump just beneath the abdominal wall and the long loops of antecolic jejunum making easy further resection of the stomach and jejunal segment.

In our surgical experience with the treatment of peptic ulcer in this series by means of subtotal gastrectomy, we have demonstrated in 5 cases gastrojejunal ulcer involving the jejunum at the anastomosis to the stump of the stomach. This is the fourth group to be considered. Every surgeon who has dealt with the problem of subtotal gastrectomy for ulcer must admit the possibility of a gastrojejunal ulcer even after this operation. With that in mind, we have repeatedly stressed the need for consideration of such a possibility when the subtotal gastrectomy is undertaken, and the need of so doing the operation that should a gastrojejunal ulcer occur it can be handled satisfactorily. For a number of years, in all subtotal gastrectomies we have employed antecolic anastomosis to the stump of the remaining stomach, without jejunojejunostomy.

This procedure has now been used in a sufficient number of cases without the production of obstruction and with satisfactory function so that we believe it not only has no disadvantages but many advantages (Fig. 10).

Its primary advantage concerns this fourth type of complicated ulcer problem, that is, secondary resection of the stomach when gastrojejunal ulcer follows a high subtotal gastrectomy, with which we have had to deal in the 5 cases. It is here with the antecolic anastomosis with long loops available in front of the transverse colon, with the indurated gastrojejunal ulcer in the gastric stump free in the abdomen, and with the gastric stump accessible in front of the transverse colon, that secondary resection after previous subtotal gastrectomy can most easily and safely be done (Fig. 10).

We present this method of anastomosis which we have now employed for many years not only for ulcer but also for cancer, not as an argument against the continued use of posterior retrocolic anastomosis of the jejunum to the gastric stump after subtotal gastrectomy, except on the basis that when gastrojejunal ulcer occurs in the posterior anastomosis, the exudate can well involve the root of the mesentery of the transverse colon, the middle colic artery, and may do so to the extent that it is impossible to preserve this vessel. Thus, in addition to subtotal gastrectomy, with such a complication it has sometimes been necessary to do a resection of the transverse colon.

We personally wish to express our preference for the antecolic anastomosis without enteroenterostomy, because it provides a large amount of alkaline jejunal content in the long loop to be dumped into the stomach to help neutralize the gastric acidity, and because it functions so satisfactorily without complications. We have had no obstruction or ballooning of the proximal loop. In only 2 cases, early in our experience before we dared to wait, was reoperation done because of failure of the anastomosis to drain, and in neither case was anything done because the obstruction was found to be due to edema and was relieved with no technical step whatever applied to the anastomosis. In the large series of cases in which we have performed subtotal gastrectomy, not only for ulcer but also for cancer, and even in most of the 54 cases in which we have now done a total gastrectomy, antecolic-jejunal-gastric and antecolic-jejunal-esophageal anastomosis have been done without enteroenterostomy and without complicating obstruction.

There is little to be said regarding the management of recurrent jejunal ulcer after subtotal gastrectomy except to call attention to the fact that in such a case a secondary subtotal gastrectomy is much easier and safer to perform when the anastomosis is of the antecolic type without lateral jejunojejunal anastomosis than when it is a retrocolic anastomosis.

SUMMARY

1. The surgical management of some of the more complicated peptic ulcers in the last 251 consecutive operative cases is discussed.

2. Of the 7,000 patients with ulcer whom we have hospitalized on medical management, 18.1 per cent of the gastric ulcer patients and 6.59 per cent of the duodenal ulcer patients were submitted to operation.

3. A mortality rate of 2.7 per cent is reported in all gastric, duodenal and gastrojejunal ulcers, exclusive of gastrojejunocolic fistula.

4. A mortality rate of 3.2 per cent is reported in 251 subtotal resections for ulcer of all types—gastric, duodenal, gastrojejunal and including gastrojejunocolic fistula.

5. A mortality rate of 4.4 per cent is reported in 46 consecutive subtotal gastric resections performed solely for gastrojejunal ulcer.

6. Conservative operative methods are occasionally imperative to avoid high operative mortality in certain densely adherent duodenal ulcers or ulcers arising low in the duodenum and involving the common duct.

7. Radical subtotal gastrectomy is necessary for relief of the surgical gastrojejunal ulcer. Temporizing operative procedures in view of the possibility of recurrent ulcer serve only to increase further the operative risk.

ONE STAGE COMBINED ABDOMINOPERINEAL RESECTION FOR MALIGNANT TUMORS OF THE RECTUM, RECTOSIGMOID, AND LOWER PART OF SIGMOID

CHARLES W. MAYO, M.D., F.A.C.S., Rochester, Minnesota

FOR some time it has been my opinion, which has been shared by others, that in the majority of cases of malignant growths of the rectum, rectosigmoid, and lower portion of the sigmoid, one stage combined abdominoperineal resection, when feasible, is the surgical procedure of choice, because it best satisfies the guiding principles of therapeutics for the pathological condition and for the patient.

This statement can be shown to be true for a particular surgeon only if a review of his cases demonstrates that such treatment was justified, and such justification is determined by the results obtained from the way in which he happened to deal with patients. If results are poor, it does not follow that he should discard one-stage combined abdominoperineal resection, but rather, perhaps, that the method of doing it should be discarded. If results are good, it also follows that they are never so good that they cannot be improved. It is, therefore, with the purpose of re-evaluation of my own opinion of one-stage combined abdominoperineal resection that this study is undertaken.

Without further elaboration, it is to be understood that my initiation and efforts in this particular surgical approach to the problem have been stimulated by the many excellent teachers and writers on this subject abroad and in this country.

The study is based on a consecutive and all-inclusive series of 276 cases in which I have performed the operation under discussion. In these 276 cases, counting deaths from all causes, regardless of the length of the hospital stay, 17 patients died.

There are many ways to break down any group of cases in an effort to arrive at answers to questions which may be thought to be important. Too minute divisions, without sufficient numbers in any division, are likely to lead to the formation of false conclusions by the imputing of qualities or blame undeservedly to a method or to a detail of the therapeutic picture; therefore, no effort will be made in this article to intimate a supposed fact unless it is justified by a sufficient number of cases.

My experience with the one stage combined abdominoperineal resection reached a point at which I felt that I had accumulated enough cases to review them very critically, individually and as a group. At that time I had performed 105 such operations, with 15 postoperative deaths. As a result of the study, I was convinced that the mortality rate was too high; that if improvement was to be made, changes had to take place somewhere along the line, in preoperative preparation, in the surgical procedure itself (which includes anesthesia), and in the postoperative care. I had still another premise, and that was that each change must be simple and logical.

In the last 171 cases in which I performed one stage combined abdominoperineal resection for malignant growths of the rectum, rectosigmoid, and lower part of the sigmoid, there were 2 postoperative deaths. One death was caused by peritonitis which resulted from an abscess that developed just above the sacral promontory and ruptured intraperitoneally on the 12th day after operation; the lesion in this case was a lymphosarcoma, grade 4, of the rectum. The other death, also in a man, occurred on the 9th postoperative day as a result of sudden and massive pulmonary embolism. This man weighed 235 pounds (106 kg.) and was operated on for a grade 1 (type A, according to Dukes' classification) lesion of the rectum.

From the Division of Surgery, Mayo Clinic.

Read before the meeting of the Inter-State Post Graduate Medical Association, Chicago, Illinois, October 26 to 30, 1942.

The abrupt and, up to this time, lasting improvement in the surgical mortality rate is another justification for the present report. It is my intention to consider herein those measures in the preoperative preparation, anesthesia, the operation, and the postoperative care, which have had a major part in the improved results obtained.

PREOPERATIVE PREPARATION

Let me now consider points in the preoperative preparation.

First, the patient is admitted to the hospital for preparation at least 48 hours before operation.

Second, any patient who has a malignant tumor in the anus, rectum, rectosigmoid, or lower part of the sigmoid for whom there is the remote possibility of performance of a one stage combined abdominoperineal resection is prepared preoperatively for it (that is, the fact that a growth feels firmly fixed on examination from below does not justify the assumption that it will not be possible to perform the operation, after surgical exploration from above). It is assumed that the patient has been properly shaved and has come to the operating table with an indwelling urethral catheter accurately in place. Thus will be avoided unnecessary delay on the operating table or, perhaps, a second choice type of operative procedure.

Third, measures for the emptying and cleansing of the colon may vary, depending on the degree of obstruction present and, unfortunately, on the question of whether or not barium has been given by mouth. Although few patients will require any preliminary measure, such as cecostomy, if obstruction is marked the case usually is not one in which the one-stage operation should be selected. Unless the bowel is well emptied, such a major surgical procedure as that under discussion should not be attempted. A well prepared bowel is an essential if a low mortality rate is to be maintained for this operation. Use of a high carbohydrate, nonresidue diet, the taking of laxative agents by mouth (I use phosphosoda) and irrigations administered from below with the patient in the knee-chest position, repeated as indicated, will suffice to empty and sufficiently cleanse the colon in most instances.

Fourth, if debility, dehydration, anemia, or other complicating features exist and can be rectified within a comparatively short time to such a degree that a major surgical procedure is not contraindicated, they should not, in themselves, prevent the operation. Evaluation as to the patient's reserve powers against the shock of a major operation is to be made in all cases, and possible complications are to be anticipated by the use of preoperative measures.

Fifth, mental preparation is, I believe, important. When a surgeon plans a one stage combined abdominoperineal resection, he is not always able to complete the plan after surgical exploration has been carried out; therefore, it is important for him not to commit himself beforehand. Most patients will know or, at least, have a good idea, of what their trouble is, before operation. Mental preparation should, for the most part, evolve from mental adjustment to the possible performance of colostomy. The surgeon should beware of a patient who is sure before operation that death will ensue.

Sixth, antiperitonitis vaccine, in doses of 1 to 1.5 cubic centimeters, is injected with a dull pointed needle, intraperitoneally, in the right lower abdominal quadrant 48 hours before operation. It is my opinion that this is a therapeutic adjunct, not a panacea; and although I cannot accurately evaluate its usefulness, at least I have never had experience with it in any case in which I could see it was harmful, and indications are that deaths from peritonitis are fewer in those cases of lesions of the colon in which it has been employed than in those in which it has not been used.

ANESTHESIA

Next, the subject of anesthesia can be discussed appropriately. The type of anesthesia which has been used in the vast majority of cases on my service for this operation has been a combination of spinal anesthesia—with procaine hydrochloride or benzoyl-gamma-(2 methylpiperidino)-propanol hydrochloride (metycaine)—and intravenous anesthesia with pentothal sodium. There have been a few

exceptions to this procedure, as determined by the judgment of the anesthetist. This follows the axiomatic statement that the anesthetic agent to use in any case is that with which the anesthetist is most familiar and which is best suited to the individual case.

In my opinion, timing of the combining of spinal and intravenous anesthesia is important. One should not delay use of any combination type of anesthesia until the effect of the first type used gives evidence of wearing off. We anesthetize the patient by the intravenous technique, approximately at the time the abdominal incision is made and continue this form of anesthesia until the posterior resection has been completed.

The dosage of the spinal anesthetic agent is the same as that which would be used were combined anesthesia not contemplated. The dosage of pentothal sodium will vary, depending on the response of the individual patient to it. Oxygen of a high concentration also can be administered by the inhalation mask, with apparent benefit.

A more detailed discussion of the subject of combined spinal and intravenous anesthesia for operations on the colon has been published elsewhere.

Additional supportive measures may be indicated during the course of the actual operation, such as those required because of an unusual decrease or increase in the patient's blood pressure or an unusual loss of blood; these measures should be thought of as something to be carried out immediately, and not after operation. Frequently, solutions of sodium chloride or of glucose are administered intravenously and, more occasionally, blood is transfused at the time the patient is on the operating table.

OPERATIVE METHOD

An essential of the carrying out of any operative method is a thorough understanding on the part of the surgical team of the details of that method, from the time the patient is placed on the operating table until he is moved off. This will avoid unnecessary and even hazardous motions and loss of valuable time and make for the efficiency and pleasure of all concerned.

I have no quarrel with the surgeon who prefers other types of instruments or suture material than those which I use. A difference of opinion might be based on how the instruments and suture material were used, rather than on the instruments and materials themselves.

What will be presented here is a description of a method of one stage combined abdominoperineal resection which has given good results.

The incision. A low abdominal incision is made approximately 1 inch (2.5 cm.) from the midline, through the anterior fascia of the left rectus muscle, and the muscle is retracted laterally. This incision is selected because it interferes the least with the blood and nerve supply to that muscle, and experience has proved that it is a good one through which to work in order to complete the operation in one stage, to set the stage for a two stage combined abdominoperineal resection, to create a permanent type of colonic stoma, or to close as only an exploratory operation.

Exploration. The purpose of examination of the abdominal cavity is to determine the feasibility and justifiability of the operation in one stage. Gross evidence of distant metastases, particularly in the lobes of the liver, is felt for; the abdominal portion of colon should be palpated carefully, with the realization that in 5 per cent of cases of malignant processes of the colon the condition is multiple; fixation of the lesion itself is estimated. The combination of observations determines the question as to whether or not one stage combined abdominoperineal resection should be attempted. There are, of course, all degrees of indications in the observations and, as time goes on and experience accumulates, the surgeon is tempted to assume greater and greater risks. A small degree of metastasis to the liver with a primary movable lesion of the rectosigmoid, for instance, would not necessarily contraindicate the operation, nor would obesity itself or a movable, additional, small, nonobstructing lesion in the transverse colon or splenic flexure contraindicate it.

Operation proper. If the decision is made to proceed with the surgical maneuver planned on, the incision is enlarged to an adequate size.

It is a mistake to work through too small an incision. Dr. William J. Mayo used to say that it was well to remember that an incision heals from side to side, not from end to end.

The next step is to examine the sigmoid carefully, principally so that it can be decided at which point colostomy should be performed. This depends on the mobility of the colon and mainly on how much, if any, redundancy exists. Colostomy is not to be standardized: a point in the incision will be found where the portion of bowel to be exteriorized will come out the easiest and it should be so planned that, if possible, about 3 inches (about 8 cm.) of colon will protrude beyond the margin of the skin. Also, this point in the bowel should be so selected that there will be very little redundant bowel proximal to the colonic stoma, so that prolapse at a later time will be avoided.

When the site in the sigmoid colon has been selected for colostomy, a rubber tube is run through the mesosigmoid next to the bowel and then, with the patient in the Trendelenburg position, the small intestine is packed away from the region of dissection.

Dissection of the lower segment of colon is begun just below the rubber tube which has been placed at the point selected for colostomy. The peritoneal covering of the mesosigmoid is peeled back, so that the branches of the sigmoidal vessels are exposed; these branches are ligated. This procedure is continued until clamps can be applied high on the superior hemorrhoidal artery. Usually, the site for application of the clamps will be 3 to 4 inches (about 8 to 10 cm.) above the promontory of the sacrum. Looking forward to the stage in the procedure at which the pelvic peritoneum must be closed, it is important to preserve as much healthy peritoneum as possible during these first steps. The right ureter is very easily avoided; the left, particularly in obese patients, must be more carefully protected because the left position of the mesosigmoid makes it more vulnerable than the right one.

Up to this point, the dissection has been carried out above the rectum, posteriorly and bilaterally. If rectal dissection is next carried out posteriorly to the tip of the coccyx and laterally approaching anteriorly, as well as is possible in the individual case, anterior dissection will be more easily accomplished because of the increased mobility. Long scissors will be a distinct advantage. The lines of cleavage of the fascial planes should be followed and the surgeon should keep ever before him the objective, which is to stay well away from the involved tissues. Each case will be different in respect to the ease of this part of the dissection. Effort should be made to accomplish as much of the rectal dissection from above as possible, for this technique will facilitate the work posteriorly. When as much as can be done has been done, the surgeon should not keep trying to do more.

Next, attention is directed toward placement of the colonic stoma. Again, the proximal portion of sigmoid is pulled up and the point in the incision through which the bowel will pass most naturally is marked. Here the subcutaneous fat is pushed laterally from the anterior rectus fascia, muscle from the undersurface and muscle from the anterior surface are separated laterally from the posterior fascia, the anterior and posterior fascia are then cut transversely, and the left rectus muscle is separated with curved forceps in such a manner as to leave about 1 inch (2.5 cm.) of muscle on the mesial side. The fascia is cut thus in order not to strangulate that portion of bowel which is to form the colonic stoma.

Long Payr clamps are slid through the split in the left rectus muscle and are applied at the desired point on the sigmoid. A smaller Payr clamp is placed on the lower part of the sigmoid, the bowel having been elevated in such a manner as to allow removal of any redundant portion. It is important to leave no more bowel to be placed in the dissected rectal space of the sacrum than necessary.

The next step is to close the distal stump of sigmoid. Closure is accomplished by an over-and-over stitch across the closed Payr clamps. By withdrawal of the clamp, as the suture is pulled, the crushed portion is inverted. The lower segment of colon is now placed deep under the pelvic floor and the peritoneal edges are brought together with double strands of No. 1 chromic catgut, and, beginning at the base of the bladder in the male and at the base

of the uterus in the female (if she has not been divested of this organ), this suture is continued to the point at which the mesentery of the sigmoid is to penetrate the posterior rectus fascia and there it is locked.

At this stage decision is made for or against closure of the lateral space between the site of colostomy and the abdominal wall. The rule which I follow is: (1) close small openings and leave large ones open and (2) close nothing under tension. Actually, I will close only a small percentage of openings. Having either closed or left the aforementioned space open, I now continue, with the suture with which the new pelvic floor has been approximated, to close that portion of the abdominal incision lying below the colonic stoma.

The abdominal pack is removed next and the patient is moved from the Trendelenburg position into the horizontal position, and the upper portion of the abdominal incision is closed. Care is taken not to close incision too tightly around colonic stoma; a finger should slip in easily between bowel and fascia.

After closure of the skin has been carried out, a fishline pursestring suture is placed just below the Payr clamp on the single barrel colonic stoma; the clamp is removed and a rectal tube is placed about a half inch (about 1 cm.) into the lumen of the bowel, where it is fixed in place. It is most important to be certain that the tube does not extend below the margins of the skin. Edema and swelling may sever the bowel between the fascia and the rubber tube, should the tube be allowed to go in too far.

The anterior wound is then dressed so as to avoid pressure on the extruding colonic stoma and the patient is placed carefully in the lithotomy position. The buttocks and anus are cleansed and a pursestring suture of the fishline is placed about the anus to prevent leakage. A triangular incision next is made, the base being up and the apex being at the tip of the coccyx. The size of the triangle will depend on the situation of the malignant lesion; for those situated high it need not be as extensive as for those situated low. The coccyx need not be removed. I have never removed it in this operation and I know of no case in which it had to be removed later on.

If dissection has been carried out, as would be preferred, from above, posterior resection is comparatively simple, infrequently requiring more than from 10 to 15 minutes for completion. Bleeding points are caught and ligated, and after the posterior cavity has been swabbed with tincture of sodium ethylmercurithiosalicylate (merthiolate) and 75 grains (4.9 gm.) of sulfanilamide crystals have been placed in it, a rubber composition sheet (pliofilm) is placed over the opening and a long gauze strip is packed snugly into the cavity for a twofold purpose: (1) to control bleeding and (2) to support the new pelvic floor against immediate stress and strain.

The posterior pack is left in place for 4 days and the single stitch that has kept it in place is then removed and the pack is gently pulled out, care being taken that it does not create suction by being removed like a cork. Very little, if any, sedation is required for removal of the posterior pack.

POSTOPERATIVE CARE

Postoperative care can be divided roughly into two important divisions: (1) general supportive measures and (2) local care of the wounds. It is understood without elaboration that competent nurses must have a thorough understanding of the nature of the operation and of the details of carrying out postoperative orders, for in their heads and hands much of the responsibility lies.

General measures. Transfusion of blood: All patients, regardless of how well they may have tolerated the actual surgical procedure, receive 500 cubic centimeters of whole blood by transfusion. If there is any question as to whether more blood is needed, the element of doubt alone is taken as an indication that it is, and then 1,000, instead of 500, cubic centimeters of blood is transfused. It is well to state here that before operation, in anticipation of the need for transfusion, the blood of the patient should be typed, as should also that of the relatives, as potential donors.

Oxygen: All patients receive postoperatively high concentrations of oxygen, either in the oxygen tent, where the concentration is kept in the vicinity of 50 per cent, or by means of the B.L.B. mask (nasal or oronasal, as indi-

cated), in which the concentration approaches 100 per cent. The minimal duration of administration is 24 hours, but oxygen can be given for longer periods, if it is indicated.

Activity: At the clinic we like to keep our patients moving in bed and to have them up and out of bed at the earliest opportunity. The magnitude of the operation is too likely to be assumed to be an indication for prolonged rest in bed. Unless it is contraindicated, however, and it rarely is, our patients "dangle" (swing the feet off the side of the bed and remain in a sitting position for a short time) morning and afternoon of the 9th postoperative day, and get out of bed on the 10th day, at which time daily sitz baths are begun. Between 80 and 85 per cent of patients can be up and out of the hospital in less than 3 weeks after the operation. They should not be permitted to make invalids of themselves.

Mental attitude: It is the obligation of the physicians and nurses in attendance to aid, by every means possible, in the adjustment of the patient to the acceptance of a permanent colonic stoma. The patient's natural tendency is to think only of the bad features of a colonic stoma and the probable limitations in habits of living which will ensue.

Care of the abdominal and posterior wounds. Abdominal wound: Strict adherence to certain principles will have much to do with what may be termed a "good" abdominal wound. First, it should be kept unsoiled by fecal material for as long as possible. The rectal tube tied in the lumen of the colonic stoma, as previously described, aids in this. Second, when soiling finally becomes unavoidable, fecal material must not be allowed to remain in contact with the wound. Close attention by a nurse is a requisite and frequent exposure of the wound under a cradle, with or without the application of dry heat, is mandatory. Third, undue pressure must not be exerted on the colonic stoma. It should be dressed with a doughnut type of dressing, about the protruding portion of bowel.

Posterior wound: The posterior wound is left practically undisturbed until the 4th postoperative day, at which time the pack is removed. Our efforts are bent toward keeping the outer part of the wound wide open by daily examination with the sterile gloved finger, so as to avoid pocketing deep in the wound. Slight "spiking" of the temperature postoperatively from about the 8th day on frequently will be caused by walled off pockets in the posterior wound.

Cleanliness and stimulation of clear granulation tissue are achieved by irrigation, twice daily, with an 0.8 per cent solution of sulfanilamide, alternating with a quarter strength solution of hydrogen peroxide, and also by daily sitz baths, from the 10th day on, when the patient is out of bed. The vast majority of these patients can sit with surprising comfort from this time on, and by the 6th week the posterior wound generally is well on toward complete healing.

The sum and substance of dealing with the posterior wound is to allow it to heal cleanly from within outward.

CONCLUSION

Although I have spoken generally of a series in which one stage combined abdominoperineal resection has been performed 276 consecutive times on my surgical service up to October 3, 1942, and in which there were 17 postoperative deaths, or a mortality rate of 6.15 per cent, my main attention has been given to analysis of the preoperative care, the surgical details, and the postoperative attention in the last 171 cases in which 2 deaths have occurred (counting all postoperative deaths from any cause regardless of the time the patient spent in the hospital) resulting in a mortality rate of 1.17 per cent.

The purpose of the study has been to present those factors in the care of these patients which I feel have had a major rôle in bringing about the improvement in this latter series of one stage combined abdominoperineal resection.

REFERENCES

1. Anderson, B. M., Mousel, L. H., and Mayo, C. W. Surg. Gyn. Obst., 1942, 75: 651–656.

THE EFFECT OF HEPARIN ON WOUND HEALING

HAROLD LAUFMAN, M.D., Captain M.C., U.S.A., and
RICHARD E. HELLER, M.D., Captain M.C., U.S.A., Chicago, Illinois

THE anticoagulant action of heparin has made this substance a valuable adjunct in the prevention and treatment of thrombosis. Recent experiments indicate that heparin might inhibit the formation of intraperitoneal and intrapleural adhesions. If this be true, it raises the question as to what effect heparin might have upon the healing properties of a surgically induced wound. It is this question which we undertook to answer in our experiments.

The indications and limitations for the use of heparin are not as yet well defined despite much excellent clinical work on the subject. This is probably due to the fact that its mode of action is not completely understood. It is hoped that our experiments might shed some light on this problem.

Occasional cases of wound dehiscence following the postoperative use of heparin have been called to our attention. However, because of certain extraneous factors influencing the efficiency of wound healing in these cases, we were not convinced that heparin was the cause of wound disruption. It seemed proper, therefore, that a controlled study of the problem be undertaken.

Mason has shown that heparin apparently does not inhibit the healing of incisions in blood vessels. Bendix has studied the effect of heparin on the healing of gastric incisions in rats, using a compressed air distention technique. He found no appreciable effect on the 5th postoperative day.

METHOD

In our experiments some 80 mongrel dogs of about the same weight were used. Under nembutal anesthesia and the usual aseptic precautions an incision exactly 3 inches long was made in the upper midline of the dog's abdominal wall. The umbilical area was not incised. The incision was made through the linea alba so that no muscle was cut or separated. The peritoneum, which is adherent to the endoabdominal fascia in the dog's abdominal midline, was opened with the other mural structures.

The method of closure was identical in each animal. It consisted of placing 7 interrupted sutures of the No. 00 chromic catgut[1] to approximate the wound, each suture including all the mural structures. All bleeding points were carefully clamped and ligated with fine silk. The skin was closed with a fine subcuticular suture of fine silk.

Two series of dogs were followed. One series received multiple intravenous injections of heparin[2] so that the coagulation was at all times kept above normal, ranging from 5 to 120 minutes. In the control series the same operation was carried out but the animals received no heparin. At the time of wound disruption, blood protein and blood vitamin C determinations were made in order to rule out a deficiency of these factors as a cause of poor handling.

Groups of animals in each series were subjected to a wound disruption test at intervals between 1 and 22 days after operation. Daily tests were carried out between the 1st and 8th postoperative days. Because of the large number of animals used in the experiments we were desirous of finding a means of testing wound strength which would not necessitate the removal of a section of abdominal wall and the sacrifice of otherwise healthy dogs. We therefore devised a method which, though not quantitatively accurate, gave a qualitative or comparative determination of the amount of force necessary to disrupt the wounds. A specially designed instrument was built which

From the Division of Surgery, Northwestern University Medical School.

[1] Ethicon chromic (J. & J.) No. 00 meets the requirements stipulated in the U. S. Pharmacopoeia XI, 2d supplement, being 5 pounds, minimum average tensile strength on the straight pull, and 3 pounds minimum average over the surgeon's knot.

[2] Liquaemin (Roche-Organon, Inc.).

TABLE I.—TENSILE STRENGTH OF A STANDARD TYPE OF ABDOMINAL WOUND IN THE DOG

Normal animals			Heparinized animals		
Age of wound in days	Force, in pounds, necessary to disrupt wound	Average	Age of wound in days	Force, in pounds, necessary to disrupt wound	Average
2	35	40	2	34	39
	35			35	
	40			35	
	55			40	
	35			50	
3	34	45	3	5	14
	35			12	
	45			15	
	55			20	
	55			20	
4	30	31	4	28	36
	30			30	
	30			50	
	35			40	
5	28	35	5	35	45
	30			45	
	30			48	
	40			35	
	50			55	
6	45	38	6	35	40
	38			50	
	25			46	
	45			28	
7	35	37	7	40	41
	32			45	
	35			40	
	36			38	
	46				
8	50	67	8	Normal tissue tore at 65 lbs., with wound still intact	
15	Wound withstood 100 lbs. tension				
22	Wound withstood 65 lbs. tension though normal structures tore			50	

consisted of two opposing retractor hooks mounted on a metal rod. One hook was stationary, while the other was attached to a sliding flange. The flange, in turn, was attached to a spring scale graduated in pounds (Fig. 1). The retractor hooks were inserted into small puncture wounds placed ½ inch on either side of the middle of the incision. These wounds penetrated the entire thickness of the abdominal wall. By turning a crank mounted on threads, the retractor hooks were gradually separated. The maximal reading on the scale before actual disruption of a part or all of the mural structures (not skin) was taken as the force in pounds necessary to disrupt the wound.

We were aware of the fact that certain tangential forces were dissipated above and below the puncture wounds. However, repeated determinations convinced us that these factors could be considered as more or less constant and could be disregarded as a source of error in purely qualitative determinations.

After the strength of the wound was tested the puncture holes and the ruptured incision were sutured, thus allowing the animals to survive for use in other experimental work.

RESULTS

The tension force representing the degree of disruptibility in our control animals gave a fair index of the healing powers of a surgically induced abdominal wound in the dog when the blood protein and blood vitamin C levels are within normal limits (Table I).

In the control series, the wound was found to be weakest on the 4th and 5th postoperative days. The average disruption force in pounds for these days was 31 and 35, respectively. In the heparinized series, the wound was weakest on the 3d postoperative day, at which time the disruption forces averaged only 14 pounds. It was found that beyond the 5th postoperative day, the wound in both the heparinized and control series followed somewhat similar strength curves, so that it was concluded that heparin had no effect on the healing powers of an abdominal wall incision beyond the 5th postoperative day.

The only remarkable variance from the consistent results were instances in which there was found to be an abnormal amount of blood accumulated in the intramural tissues. It is well known that an excess amount of blood within the region of a healing wound will retard the progress of healing. It was

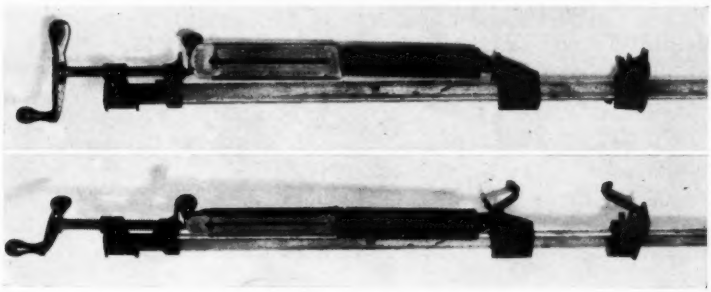


Fig. 1. Two views of wound disruptor used in testing tensile strength of abdominal wound in the intact animal.

assumed, therefore, that in such cases the hemostasis was not adequate enough to prevent the pooling of harmful amounts of blood in the healing wound after the administration of heparin. Those instances in which hemostasis proved adequate showed no remarkable difference between the heparinized and controlled series beyond the 5th postoperative day.

Laufman has shown that bleeding may resume after the administration of heparin, despite grossly satisfactory hemostasis at time of operation. There were several instances in each series in which the skin portion of the wound was found disrupted after the 3d postoperative day, with the mural portion nevertheless healing satisfactorily. Such skin disruption occurred spontaneously in 6 of the heparinized animals and in only 1 of the control animals. The potential space between fascia and skin, consisting of loosely packed subcutaneous fat makes an ideal pocket for hematoma formation. In no instance in either series was there spontaneous disruption of all of the structures of the abdominal wall.

Although our tests began with the 1st postoperative day, it soon became apparent that the tests were not of great significance until at least the 3d postoperative day, because of the holding power of the catgut. The fact that the heparinized animals had a comparatively weak wound on the 3d postoperative day when compared with the control series, made us wonder whether the catgut actually dissolved more rapidly in the presence of heparin. Isolated *in vitro* experiments, however, subsequently showed this to be untrue. Heparin did not hasten the dissolution of catgut.

Microscopic sections of wounds representing various stages of healing in control and heparinized animals were stained with Weigert's gram method[1] for fibrin. Up to and including the 3d postoperative day the wounds of heparinized animals were found to contain somewhat less fibrin than did the wounds of control animals. By the 4th and 5th postoperative days, however, the wounds of both the heparinized and control animals appeared to contain about the same amount of the bridging substance. It became apparent, therefore, that although heparin delayed the laying down of fibrin, it did not altogether prevent the process. By the 4th or 5th postoperative day the deposition of fibrin in the wound of heparinized animals apparently "caught up" to that in the control, despite a delay for the first 3 days. The growth of fibroblasts was altogether unaffected by heparin.

OBSERVATIONS

The exact mode of action of heparin is still controversial. There is, however, some agreement that it acts both as an antithrombin and an antiprothrombin. From all the available evidence, D'Alessandro concluded that heparin (activated by plasma) and thrombokinase are antagonistic, and that one promotes and the other inhibits the conversion of prothrombin to thrombin. Within certain limits of concentration, an excess of either counteracts the effect of the other. If this premise be accepted, heparin indirectly inhibits the formation of fibrin from fibrinogen. However, our experiments indicate that although the

[1]Using crystal violet and Lugol's solution and clearing in alcohol.

coagulation time of the blood is prolonged by heparin, such prolongation does not necessarily prevent, but merely delays the deposition of extravascular fibrin.

CONCLUSION

In experimental studies on dogs, it was found that heparin had no appreciable effect upon the healing process of surgically produced abdominal wounds in dogs whose blood protein and blood vitamin C levels were within normal limits. The only deleterious action exerted by heparin upon the healing powers of a wound was the pooling of blood within the wound. This accumulation of blood in the presence of heparinization was apparently due either to inadequate hemostasis at the time of operation, or the resumption of bleeding in the wound after apparently adequate hemostasis at time of operation. Heparin appeared to delay the healing process slightly up to the 4th postoperative day but after that it had no real effect.

We again emphasize, as have others, that when it is necessary to administer heparin after operation, the most meticulous hemostatic precautions be taken at time of operation. Whenever possible nonabsorbable or slowly absorbable suture material should be used.

REFERENCES

1. Bendix, R. Personal communication. Unpublished results.
2. D'Alessandro, A. J. Surg. Gyn. Obst. (Internat. Abstr. Surg.), 1942, 74: 62.
3. Laufman, H. Surg. Gyn. Obst., 1942, 74: 479.
4. Mason. Quoted by D'Alessandro. Loc. cit.

THE USE OF VENOGRAMS FOR THE LOCALIZATION AND STUDY OF ARTERIOVENOUS FISTULA

JAMES R. WATSON, M.D., F.A.C.S., J. M. LICHTY, M.D., F.A.C.P., J. M. HILL, M.D., and R. B. MILLER, M.D., Pittsburgh, Pennsylvania

VENOGRAPHY has become a well established procedure. The ease and safety with which it can be carried out makes it of material value in both the diagnosis and localization of lesions of the veins of the extremities. Its use has been confined principally to the study of venous thrombosis, and excellent treatises on this aspect, as well as detailed accounts of the technique, have been provided by Dougherty and Homans, and by Bauer. Bauer suggested that it might also be of value in the study of arteriovenous fistulas, although he had had no opportunity to verify this impression.

Traumatic arteriovenous fistula produces profound changes in the circulatory system, and while these changes involve both the arterial and venous sides, the latter is the more adversely affected of the two and is responsible for most of the signs and symptoms which characterize the disease. The changes in the vein consist of hypertrophy and dilatation, and vary in degree according to the caliber of the vessels involved, the size of the fistula, and its duration. The dilatation may be diffuse and may extend for some distance proximal to the level of the fistula, or may be maximal locally at the site of the fistula, where it represents an almost constant finding.

The venous trunk distal to the fistula does not exhibit the degree of dilatation seen proximally. Callander has called attention to the fact that as long as the valves remain competent, no changes are apt to occur, the increased venous pressure at the level of the fistula merely obstructing the passage of blood from below by imposing an obstacle against it. Should the valves yield or become insufficient due to the increasing dilatation of the vein above them, the adjacent distal segment then undergoes the same changes that are seen above, and Holman reports such an instance in which there was a large saccular dilatation just distal to an arteriovenous fistula of the superficial femoral vessels. Such dilatation is apparently uncommon, for the arterial blood, taking the course of least resistance, passes through the fistula and into the proximal vein. The essentially normal status of the involved vein distal to the level of the fistula makes it readily adaptable for venography.

Within a period of a few months, 3 patients with arteriovenous fistulas of the common femoral vessels were admitted on the surgical service of one of us (J.R.W.). Venograms, made in each of these prior to operation, permitted us to make certain observations which we consider worth reporting. These cases are reported only in sufficient detail to correlate the findings of the venograms.

CASE 1. Willie Harrison, a colored male 49 years of age, was admitted to the Passavant Hospital in January, 1942, for treatment of an arteriovenous fistula of the right femoral vessels and a mass in the right lower abdominal quadrant. He had been shot in the posterolateral aspect of the right thigh 18 years before, when the bullet traversed the thigh and lodged just beneath the skin about 3 inches below the medial aspect of Poupart's ligament.

The positive findings on physical examination were limited entirely to the cardiovascular system. The heart was enlarged in all directions, with the maximal apex impulse in the 6th left intercostal space in the anterior axillary line. There was a systolic murmur which was best heard over the apex and which was transmitted to the left axilla and the right sternal border. A teleoroentgenogram showed the transverse diameters of the chest and heart to measure 30.5 and 20.3 centimeters, respectively. There was a large mass in the right lower abdominal quadrant which measured 14 by 10 by 7 centimeters, and which appeared to occupy most of the quadrant.

From the Passavant and Presbyterian Hospitals, and the John C. Oliver Memorial Research Fund of the St. Margarets Memorial Hospital, Pittsburgh.

Fig. 1. Normal venogram, Case 3, showing femoral and iliac veins, and valve in long saphenous vein at its junction with femoral vein. This venogram is inserted for comparison with the other venograms. The dense shadow overlying the external iliac vein is a bullet.

Fig. 2. Venogram in Case 1 showing the shadow of a normal femoral vein up to the level of the head of the femur at which point it stops abruptly. There are numerous dilated and tortuous veins present in the soft tissues of the thigh.

The right leg was much larger than the left, there being 15 centimeters difference in circumference at the mid-thigh and 7 centimeters at the mid-calf. There were varicosities and pigmentation, and in the region of the ankle there were two scars of healed varicose ulcers. There was a constant thrill and bruit over the right groin just below Poupart's ligament, the bruit being transmitted to the abdominal mass. The popliteal and dorsalis pedis vessels were not palpable.

A venogram (Figs. 1 and 2) was made of the right leg by injecting 30 cubic centimeters of a 30 per cent diodrast solution into a vein posterior to the inner malleolus. The femoral vein appeared to be normal and was visualized up to the level of the head of the femur where it stopped abruptly. There were numerous dilated and tortuous veins in the soft tissues of the thigh.

Operation consisted of quadruple ligation of the common femoral artery and vein, and obliteration of the fistula by suture. The fistula was found to be about 5 centimeters below Poupart's ligament (Fig. 3). The artery and vein above the fistula were each approximately 4 centimeters in diameter, although measurement of the vein was inaccurate as part of it lay beneath the artery. There was some sclerosis of the artery. The wall of the vein was thickened, although it was not as thick as that of the artery. The vessels below the level of the fistula were small, the artery measuring 1 centimeter in diameter while the vein was even smaller. There were several large arterial and venous branches entering the fistula, for the most part on its posterior aspect.

CASE 2. William Morrow, a white male 56 years of age, was admitted to the Presbyterian Hospital in January, 1942, for treatment of an arteriovenous fistula of the left femoral vessels. He had been injured 18 years before when a valve in the cab of a switch engine he was operating, exploded, driving a fragment of glass into the groin.

On physical examination the patient was found to be lying propped up in bed in obvious cardiac failure. He was dyspneic and slightly cyanotic. The left half of the chest was heaving forcefully with each heart beat, the impulses being visible over the carotid vessels. The superficial veins over the neck and

thorax were prominent when he was lying down but tended to disappear when he sat up. The apex impulse of the heart was maximal in the 7th left intercostal space at the anterior axillary line. There was a harsh blowing systolic murmur over the apex and aortic areas. Auricular fibrillation was present with a pulse deficit at the wrist. The blood pressure was 150 millimeters of mercury systolic and 50 millimeters diastolic. A teleoroentgenogram showed the chest and heart to measure 28.8 and 20.1 centimeters, respectively, in their transverse diameters. There were fine moist crackling râles throughout the lung fields, being most marked over the bases posteriorly. Examination of the abdomen revealed forceful pulsation of the aorta which was transmitted to the anterior abdominal wall. The liver was enlarged, extending four fingerbreadths below the costal margin. The left leg was larger than the right, with a thrill and bruit, and a visible heaving pulsation over the femoral triangle. The superficial veins were dilated and there was some pigmentation of the skin over the lower leg.

Venography (Fig. 4) was effective in localizing the fistula, a normal femoral vein being visualized to the level of the lesser trochanter where it stopped abruptly. Some of the dilated superficial veins were also visualized.

Operation consisted of quadruple ligation of the common femoral artery and vein, and excision of the segment containing the fistula. The fistula (Fig. 5) was found to be embedded in a mass of fibrous tissue and lay just above the point of origin of the profunda femoris artery. The artery above the fistula was found to be uniformly enlarged and was sclerotic. The vein was about twice the size of the artery, and above Poupart's ligament gave the appearance of being saccularly dilated. There were several large arteries and veins which communicated with the common femoral vessels above the level of the fistula and which passed over toward the pubis. There were also several other vessels which came up from the deep aspects of the thigh and communicated with the fistula in its posterior aspect. The artery and vein below the level of the fistula appeared essentially normal in size.

CASE 3. Ferdinand LePage, a 28 year old colored male, was admitted to the Passavant Hospital in April, 1941, for treatment of a type 2 lobar pneumonia. The presence of an arteriovenous fistula in the left femoral region was readily detected during a cursory examination and accounted for certain cardiovascular findings which will be described later.

During his convalescence, a more detailed history revealed that he had been admitted to the Charity Hospital of Louisiana at New Orleans 3 years previous for treatment of a gunshot wound of the left groin. The bullet had entered the groin, passed through the bladder, and had lodged in the right side of the pelvis. Information obtained from the hospital disclosed that following closure of the bladder perforations it was necessary to ligate the femoral artery and vein through a left inguinal incision to control bleeding which had become pronounced during the suprapubic operation. He made an uneventful recovery and was dismissed to the dispensary where it was subsequently found that he had developed a femoral arteriovenous fistula. The heart was enlarged, with systolic murmurs over the entire cardiac area, but there was no evidence of cardiac embarrassment. Operation was deferred to permit the development of a more adequate collateral circulation. He was apparently having no symptoms and did not return.

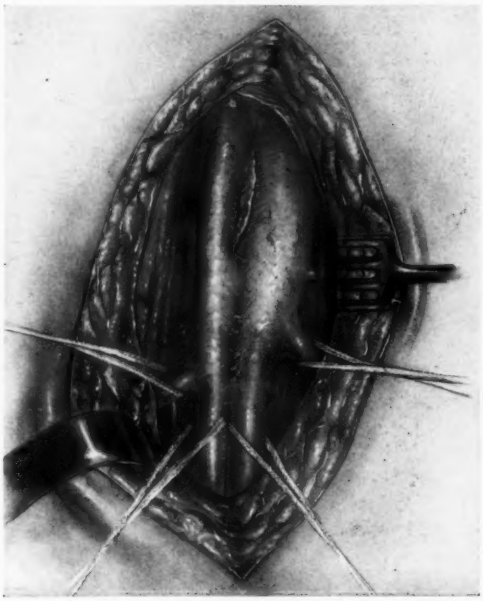


Fig. 3. Illustration of the findings at operation in Case 1. The fistula is just proximal to the profunda femoris branch of the femoral artery. The tapes are around the long saphenous and femoral veins on the left side and the profunda femoris and superficial femoral arteries on the right.

Physical examination at the Passavant Hospital showed the patient to be a well developed male. The findings referable to the cardiovascular system showed enlargement of the heart with the apex impulse in the 6th left intercostal space, 3 centimeters lateral to the midclavicular line. There was a to and fro murmur over the aortic area and a loud blowing systolic murmur over the mitral area. The pulse rate was one hundred beats per minute with a "water hammer" impulse. The blood pressure was 135 millimeters of mercury systolic and 60 millimeters diastolic. Obliteration of the fistula by digital pressure increased both the systolic and diastolic levels to 145 and 90 millimeters, respectively, and caused the pulse rate to decrease 20 beats per minute.

The abdomen was soft. The liver edge was palpated 2 fingerbreadths below the costal margin.

Fig. 4. Venogram in Case 2. The femoral vein is visualized up to the level of the lesser trochanter of the femur where the shadow stops abruptly. Some of the superficial collateral veins are also seen.

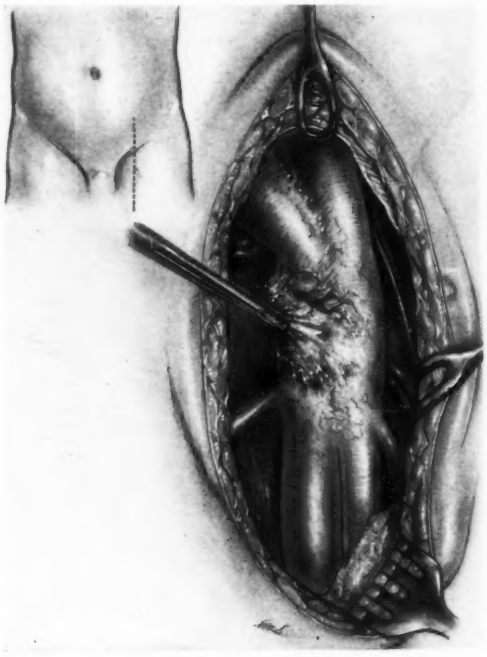


Fig. 5. Illustration of the femoral artery and vein in Case 2, with the dense fibrous tissue just above the long saphenous vein and the profunda femoris artery indicating the level of the fistula.

There were several operative scars: one midline suprapubic scar, bilateral inguinal herniorrhaphy scars, and a second scar in the left inguinal region where the femoral vessels had been ligated.

The left leg was entirely normal in external appearance, with no swelling or varicosities and no increase in the measurements when compared with the right leg. A marked thrill and bruit was present over the femoral triangle. Pulsations were palpable over the dorsalis pedis artery and could be made to disappear by compression of the fistula.

Venograms (Fig. 6) were made by the injection of 30 cubic centimeters of 30 per cent diodrast solution into the short saphenous vein in an effort to visualize the level of the fistula and the collateral venous return. The media fill both the femoral and long saphenous veins, stopping abruptly at the level of the greater trochanter. From there numerous fine streaks were seen to extend toward the pelvis, appearing even in the region of the right hip.

Operation consisted of quadruple ligation of the common femoral vessels and excision of the segment containing the fistula. The long saphenous and femoral veins were found to be slightly dilated at their juncture and were lost immediately above this in a dense mass of fibrous tissue. The common femoral artery and its profunda branch were identified at about the same level. They appeared to be about normal in size with the exception of a stricture of the common femoral artery where it passed lateral to the fibrous mass. The artery was only partially occluded and pulsated normally throughout the entire exposed length. The fistula (Fig. 7) was found above the fibrous mass and just below the level of Poupart's ligament, and blood could be seen swirling from the common femoral artery into the dilated common femoral vein. There were several small arteries and veins which communicated with the fistulous portion.

On examination of the specimen after removal, the artery above the fistula was found to measure 1 centimeter in diameter and the vein 1.7 centimeters. The fistula measured 0.4 centimeters. The common femoral vein (Fig. 8) was completely occluded just below the level of the fistula and apparently did not communicate with it. This occlusion, as well as the stricture of the artery found at the same level, was evidently the result of the ligation at the time of injury.

While the location of an ateriovenous fistula is usually readily apparent on physical ex-

Fig. 6. Venogram of the involved leg in Case 3. The media fills both the femoral and long saphenous veins, stopping abruptly at the level of the great trochanter. There are numerous fine streaks extending from this point toward the pelvis, appearing even in the region of the opposite hip.

Fig. 7. Illustration of the completed operation in Case 3. The proximal stumps of the common femoral artery and vein are seen at the upper angle of the incision, while the stumps of the long saphenous and superficial femoral veins on the left and the distal segment of the common femoral artery on right are seen at lower angle of the incision.

amination, this is not always the case. The physical signs may be inadequate or even confusing when the fistulas are small, multiple, or when they are situated in the upper mediastinum or pelvis. Venography should be of value in such instances, for in each of the 3 cases cited above, it indicated the level of the fistula as verified at operation.

Arteriography has been used for this same purpose, and several reports have appeared in the literature since Horton first called attention to its value. While we do not suggest that venography be used to supplant arteriography, there are instances in which it may be the only method applicable, such as for the demonstration of fistulas at or proximal to the roots of the extremities, where injection of the artery above the level of the fistula would be difficult or even impossible because of its anatomical position. Venography might even be used in conjunction with arteriography when the presence of multiple fistulas is suspected. In cases in which either method could be used, venography has the advantage

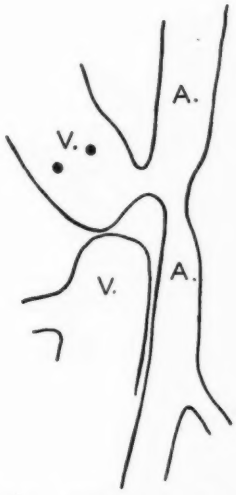


Fig. 8. Diagram of the findings in Case 3 to show the complete occlusion of the common femoral vein and the stricture of the common femoral artery just below the level of the fistula.

of permitting the use of media which are inert when injected into the venous circulation and which are readily excreted by the kidneys.

An interesting observation demonstrated by venography in one case was the effect on the extremity of ligation of the common femoral vein at the time of the injury. Brooks has stated that "If from traumatism or in the course of any operation it becomes necessary to ligate a large artery, simultaneous ligation of the concomitant vein should always be considered. . . . If the common femoral artery is ligated, I am inclined to believe that it is wiser to close the wound without ligating the vein, to watch the extremity carefully for signs of impending gangrene, and to ligate the vein only after such signs are evident. . . . In these instances, the probable immediate beneficial effects in preventing gangrene must be balanced with the possible remote ill effects of chronic venous stasis." In Case 3, ligation of the common femoral artery and vein at the time of injury 3 years before was not followed by the development of varicosities and edema. The collateral venous circulation was demonstrated by venography and consisted of numerous small venous channels which led directly from the site of ligation into the veins of the pelvis. This is in sharp contrast to the 2 other cases in which the collateral was through numerous dilated and tortuous superficial veins. Although it is impossible even to attempt a generalization from 1 case, it is worthy of note that this case was the only one of the 3 in which there were no varicosities or edema, and would at least suggest that ligation of the vein distal to the fistula at the time of injury might exert the same beneficial effect on the limb that proximal ligation exerts on the heart.

SUMMARY

1. Three cases of arteriovenous fistula of the common femoral vessels are reported in which venography was proved to be a reliable means of locating the level of the fistula.

2. Studies of the venograms in each instance showed the vein distal to the fistula to be normal.

3. The venograms demonstrated a marked difference in the collateral venous circulation between 1 case in which the vein had been ligated distal to the fistula at the time of injury for control of hemorrhage and 2 cases in which this had not been necessary.

4. Ligation of the vein distal to the fistula appears to have the same beneficial effect on the extremity that ligation proximal to the fistula has on the heart.

REFERENCES

1. Bauer, Gunnar. Acta chir. scand., 1942, 84: 56.
2. Brooks, Barney. Arch. Surg., 1929, 19: 1–24.
3. Callander, Curle L. Ann. Surg., 1920, 71: 428–459.
4. Dougherty, John, and Homans, John. Surg. Gyn. Obst., 1940, 71: 697–702.
5. Holman, Emile. Arteriovenous aneurysm. P. 149. New York: The Macmillan Co., 1937.
6. Horton, B. T. Am. J. M. Sc., 1934, 187: 649–652.

RATE OF ABSORPTION AND CALLUS[1] STIMULATING PROPERTIES OF COW HORN, IVORY, BEEF BONE AND AUTOGENOUS BONE

CHARLES W. HUGHES, M.S., M.D., Captain, M.C., U.S. A., Chicago, Illinois

DURING recent years numerous authors have reported unsatisfactory results following the use of metal internal splints in the open reduction of fractures. For this reason considerable interest has been directed toward the determination of a more satisfactory substitute for the autogenous bone graft. The majority of the papers appearing in the literature have described experimental and clinical results obtained by means of various organic animal substances which have been used as internal splints.

Boliarsky, Dahl-Iversen, Fowler (12, 13), and Lexer, have supported the use of cow horn. In 1934 Fowler (12, 13), presented evidence to show that cow horn stimulates a fractured bone to produce an excessive amount of callus. He indicated that because the horn is tough and firm but at the same time flexible and not brittle it is very adaptable for use as an intramedullary peg or onlay splint and, because it is absorbed readily, it is satisfactory from a biological aspect. Carrell and Siegling and Fahey are of the opinion that cow horn is not absorbed rapidly and that it is not a satisfactory substitute for the autogenous graft.

Ivory screws, plates, pegs, and inlays have been used to a considerable extent. In 1913 Magnuson described the following advantageous characteristics of ivory in bone: it swells as a result of the imbibition of water and becomes tightened in position; it does not produce necrosis of surrounding bone as metal does; it is absorbed and therefore obviates the need for secondary operations which are necessary sometimes for removal of nonabsorbable materials.

From the Department of Anatomy, Loyola University School of Medicine.

[1]In this paper the term "callus" is being used to describe what other authors might refer to as the reaction of bone to a foreign body.

There are numerous references in the literature to the use of beef bone as screws, intramedullary pegs, and extracortical splints. In an experimental study in which intramedullary pegs of boiled beef bone were used in fractured long bones of dogs, Davison and Christopher found that beef bone which remained in contact with the endosteum of the host bone was surrounded by living bone and became solidly embedded in new bone. It was absorbed later and replaced by living bone. Beef bone which was not in contact with endosteum was absorbed rapidly but was not replaced by living bone.

Numerous papers in the literature compare the autogenous and homogenous bone pegs. Brooks and Hudson established experimental bone defects in right and left bones of dog extremities and bridged these defects with homogenous bone in one group of dogs and autogenous bone in the other. They found that the defect was repaired in 84.8 per cent of the cases in which autogenous bone was used and in 76.8 per cent of the cases in which homogenous bone was used.

In an analysis of these papers and a review of other literature dealing with internal splints, it was found that no paper contained definite information based upon a well controlled experiment concerning the comparative rates of absorption and callus stimulating properties of the substances mentioned. In most instances deductions concerning cow horn and ivory were based upon observations of their use in fractured bones. When internal splints are used to fix the fragments of a fractured bone the rate of absorption of the splint, the callus formed about it, and the degree to which it is incorporated in new bone are all affected by: (1) the nature of the fracture, (2) the degree of immobilization, (3) the position of the splint with respect to the cortex

Fig. 1. Photograph of a dog femur (Experiment 27) 197 days after operation. The ivory peg, *I*, and cow horn peg, *H*, show no signs of absorption. The extracortical portions of the beef bone peg, *BB*, and the autogenous peg, *A*, have been absorbed. *E* was an empty hole.

(intramedullary, intracortical or extracortical position), and (4) the damage to the blood supply about the splint as a result of the fracture. As no well controlled experiment has been described from which conclusions could be drawn concerning the comparative rates of absorption of cow horn, ivory, beef bone, and autogenous bone in the medullary cavity, in the cortex and outside of the cortex of long bones, the following experiments were performed in an effort to solve the problem, to make observations concerning the comparative amounts of callus formed about the respective materials, and to study the degree to which the materials were incorporated in the host bone.

PROCEDURE

Slightly tapered cylindrical pegs ½ inch long and 1/16 inch in diameter in the middle, were prepared from ivory, cow horn, and beef bone. In a few instances (noted in Table I) the ivory pegs were boiled for 2 hours preceding sterilization in the autoclave. Dogs and rabbits were anesthetized by means of sodium barbital or nembutal given intraperitoneally. The skin was prepared for aseptic surgery by shaving, scrubbing with green soap, and application of iodine and alcohol. The proximal end of one fibula was exposed, and after the muscles were stripped from it, a portion was excised.

When dogs were used two autogenous pegs identical in shape and size with the cow horn, ivory, and beef bone pegs were carved from the piece of fibula. On the same side as that from which the piece of fibula was excised, the lateral surface of the femur and the anterior surface of the radius distal to the insertion of the supinator muscle were exposed. Four holes, 1/16 inch in diameter, were drilled through the bone cortex into the medullary cavity. These holes were arranged longitudinally along the lateral surface of the femur and along the anterior surface of the radius about ½ inch apart. One each of the autogenous, ivory, cow horn, and beef bone pegs was inserted, respectively, into the 4 holes in the femur and the radius. All of the pegs were fitted to the holes by cutting off the end with the smallest diameter so that approximately 1/16 to ⅛ inch of the tapered peg protruded into the medullary cavity. The end which projected outside of the cortex was cut so that it protruded approximately 1/16 to ⅛ inch. In this way there were intramedullary, intracortical, and extracortical portions of each peg. The incisions were all closed with catgut in the fascia and a linen subcuticular stitch in the skin.

When rabbits were used the same procedure was followed except that the piece of fibula was carved into one peg and the radius was not used.

In a few instances, as shown in Table I by a degree sign (°), a fifth hole was drilled and left empty as an additional control. The order of the pegs with respect to each other, the nutrient artery, and proximal end of the bones, was changed in various experiments to avoid misinterpretation of results because of the difference in blood supply to the various parts of a bone. Eight rabbit experiments and 21 dog experiments were performed in all.

These experimental animals were observed from 7 to 411 days before autopsy. X-ray films were made at frequent intervals during the postoperative period to study the forma-

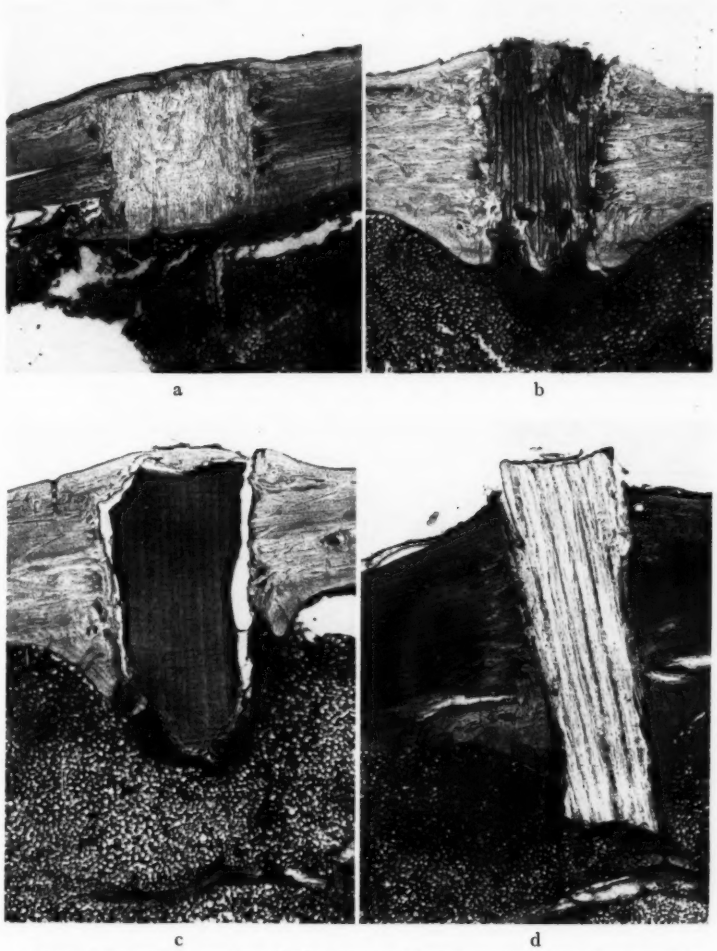


Fig. 2. Microscopic sections of the pegs and host bone 181 days after operation (Experiment 9). The autogenous peg, a, and the beef bone peg, b, are completely absorbed except for the intracortical portions. There is considerable incorporation of the pegs into the host bone. Small processes of host bone can be seen extending into the pegs. The extracortical portion of the ivory peg, c, is absorbed. The cow horn peg, d, shows no absorption. There is a definite line of demarcation between the host bone and the ivory and beef bone pegs.

tion of callus around the pegs. Photographs were made of the experimental bones after death and 15 of the specimens were decalcified, imbedded in celloidin, and sectioned.

The gross specimens, microscopic preparations, and x-ray plates were all examined by two impartial individuals besides the author to determine the extent of absorption of the various pegs. Each examiner recorded independently the degree of absorption on a scale where "7+" indicated complete absorption and restoration of contour of the host bone (see Table I).

RESULTS

An analysis of these data shows that absorption of the extracortical portion of both

TABLE I.—RECORD OF EXPERIMENTS

Experiment number	Duration of experiments—days	Animal	Type of anesthetic	Number of x-ray pictures	Positions of pegs				Absorption of pegs				Callus formation			
					1	2	3	4	A	BB	I	H	A	BB	I	H
7	6	Rabbit	Barbital	2	H	B.B.	A	I	o	o	o	o	o	o	o	o
6	35	Rabbit	Barbital	5	H	I	B.B.	A	+	+	o	o	o	o	o	o
25S	56	Dog	Nembutal	4	°I	B.B.	A	H	3+	2+	o	o	+	+	+	++
26	56	Dog-R	Nembutal	4	A	I	B.B.	H	Poor Insertion of Pegs							
10S	79	Rabbit	Nembutal	7	B.B.	I	A	H	3+	+	o	o	o	o	o	o
11S	100	Dog	Nembutal	7	Ib	H	A	B.B.	4+	2+	4+	o	4+	3+	3+	2+
12S	100	Dog-R	Nembutal	6	A	H	Ib	B.B.	3+	3+	3+	o	2+	2+	4+	3+
19S	127	Dog	Nembutal	5	°A	H	I	B.B.	3+	2+	o	o	+	2+	2+	2+
20S	127	Dog-R	Nembutal	6	A	H	I	B.B.°		4+	o	o	+	2+	3+	3+
13S	160	Rabbit	Nembutal	9	Ib	A	B.B.	H	4+	o	+	o	+	+	+	2+
5S	174	Dog	Barbital	11	A	B.B.	I	H	3+	2+	+	o	+	o	++	++
9S	181	Rabbit	Barbital	7	A	H	I	B.B.	3+	2+	o	o	o	+	2+	2+
27	197	Dog	Nembutal	3	A	H	B.B.	I°	4+	4+	o	o	2+	2+	3+	3+
28	197	Dog-R	Nembutal	3	A	H	B.B.	I°	2+	2+	+	o	o	+	3+	2+
14	240	Dog-R	Nembutal	5	B.B.	A	H	I	4+	4+	o	o	2+	3+	2+	2+
15S	240	Dog-R	Nembutal	6	I	B.B.	A	H	5+	4+	4+	o	+	3+	2+	3+
16S	270	Rabbit	Barbital	7	H	I	B.B.	A	4+	3+	2+	+	o	o	o	o
29S	287	Rabbit	Nembutal	3	°A	I	H	B.B.	5+	+	+	o	+	+	+	2+
21	306	Dog	Nembutal	2	°B.B.	A	H	I	6+	5+	+	+	2+	4+	4+	2+
22S	306	Dog-R	Nembutal	3	°B.B.	H	I	A	5+	5+	+	+	3+	4+	3+	3+
17	314	Dog	Nembutal	3	H	A	O	I	5+	4+	2+	+	o	o	o	o
18	314	Dog-R	Nembutal	4	H	A	B.B.	I	4+	4+	+	+	+	2+	+	+
23	329	Dog	Nembutal	4	°H	A	B.B.	I	4+	3+	2+	+	+	+	+	2+
24	329	Dog-R	Nembutal	3	°H	A	B.B.	I	5+	4+	2+	+	+	2+	2+	2+
8S	358	Rabbit	Barbital	7	A	I	H	B.B.	5+	2+	+	+	+	++	++	++
4	360	Dog	Barbital	7	B.B.	A	H	I	5+	4+	3+	+	2+	2+	+	+
3	367	Dog	Barbital	9	I	B.B.	H	A	3+	3+	3+	+	3+	3+	4+	3+
1	411	Dog	Barbital	8	A	H	I	B.B.	5+	5+	+	+	2+	+	3+	3+
2	Lost	Dog	Barbital	6	H	I	A	B.B.					+	3+	3+	3+
Totals: 8 rabbits, 12 dog femora, 9 dog radii.									98+	76+	34+	11+	34+	46+	53+	52+

S, Specimens which were prepared histologically; R, Radius; °, Empty drilled hole; b, boiled;
Positions: 1, most proximal; 4, most distal. A, Autogenous; B.B., beef bone; I, ivory; H, horn.

the autogenous and beef bone pegs had begun at 35 days. The ivory pegs which had been boiled were partly absorbed as early as 100 days after operation, but the pegs which were not boiled showed no signs of absorption until 174 days after operation. The first sign of absorption of any of the cow horn pegs was noted 270 days after operation. During 367 postoperative days the rate of absorption of autogenous, beef bone, ivory, and cow horn pegs follows the ratio: autogenous, 9; beef bone, 7; ivory, 3; and cow horn, 1. Figure 1 is a picture of a dog femur 197 days after operation (Experiment 27). In this picture the marked absorption of the autogenous and beef bone pegs in contrast to the very slight absorption of the cow horn and ivory pegs can be noted.

In Figure 2 the degree to which the various materials became incorporated in the host bone 181 days after operation can be observed. In the bone in which cow horn was used, d, a very distinct demarcation exists between the host bone and peg. The same is

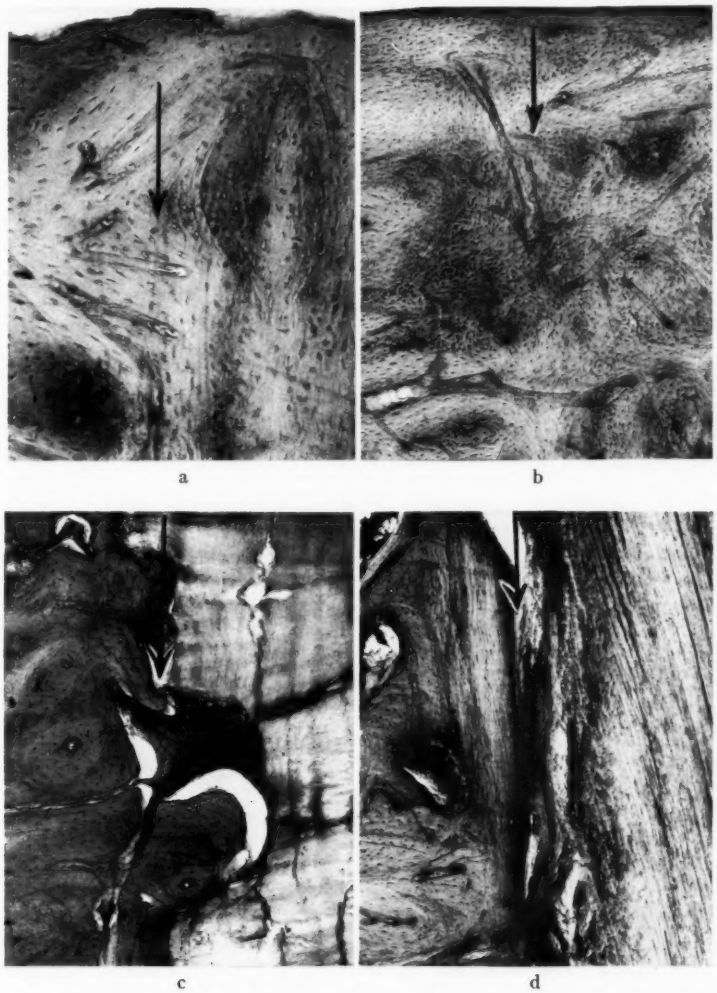


Fig. 3. The microscopic findings at the point of juncture between host bone and pegs 367 days after operation (Experiment 3). The peg is on the right in each instance. The arrow indicates the line of demarcation. The autogenous peg, a, is united with the host bone. The horizontal haversian canals of the host bone have formed connections with the vertical canals of the peg. Revascularization of the peg is occurring through these connections. The beef bone peg, b, is united with the host bone and similar revascularization has occurred. The ivory peg, c, and the cow horn peg, d, are not united with the host bone. There are no canals in cow horn or ivory and consequently absorption and replacement of these substances can take place only on the surface of the peg.

true in the case of the ivory, c. The opposite is true when beef bone, b, and autogenous bone, a, were used. In these cases it is difficult to locate the line of demarcation between host bone and peg. The horizontal haversian canals characterize the host bone while the vertical canals are more distinct in the autogenous and beef bone pegs.

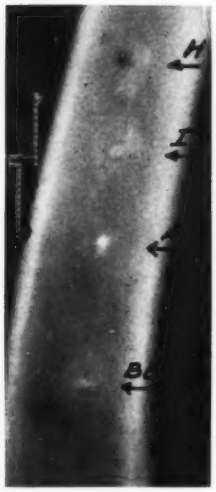


Fig. 4. An x-ray plate of a dog femur 33 days after operation (Experiment 2). Considerable callus can be seen around the cow horn peg, *H*, the ivory peg, *I*, and the beef bone peg, *BB*. There is very little callus around the autogenous peg, *A*.

Figure 3 reveals the microscopic findings 367 days after operation (Experiment 3). In Figure 3a the definite union between the autogenous graft and host bone is apparent. The horizontal haversian canals of the host bone have formed connections with the vertical canals of the graft. Revascularization of the graft occurs through these connections. Figure 3b reveals an enlargement of the haversian system of the beef bone peg. Many of the canals have changed direction as they have enlarged. Communications form between the vertical canals of the peg and the horizontal canals of the host bone. The canals in the peg enlarge as the beef bone is absorbed around the vessels in the canals and the canals change direction as new bone is formed to replace the beef bone. Figure 3c and d reveal a different situation. There are no canals in ivory or cow horn, and consequently absorption and replacement of these substances can take place only on the surface of the peg where the cortical portion of host bone joins the peg. Thus we find that beef bone is incorporated into the host bone almost as readily as autogenous bone. Cow horn and ivory remain unincorporated.

The determination of the comparative amounts of callus formed about the pegs was made from a study of the x-ray plates. This study was also made by the 2 observers mentioned earlier in the paper. The amount of callus was recorded as 0 to 4+ by the three of us independently and our results were averaged and recorded in Table I. The total number of positives recorded for each peg is: autogenous, 34; beef bone, 46; ivory, 53; and horn, 52. These figures show that there is 1.5 times as much callus formed around the pegs of ivory and horn as there is around the autogenous peg. There is 1.35 times as much callus around the peg of beef bone. The typical arrangement of callus around the pegs can be seen in Figure 4.

SUMMARY AND CONCLUSIONS

1. In long bones foreign substances which are located within bone cortex are absorbed slowly. Substances within the medullary cavity are absorbed more rapidly, and materials which are extracortical in position are absorbed most rapidly.

2. Absorption of the extracortical portion of autogenous and beef bone pegs is perceptible after 1 month. The same is perceptible in ivory (not boiled) pegs after 6 months and cow horn pegs after 9 months.

3. When the amount of callus formed around an autogenous peg is considered as a unit, there is one-third more callus around a beef bone peg and one-half more callus around ivory or cow horn pegs.

4. There is no firm union formed between ivory or cow horn pegs and the host bone. Microscopically it appears that there is definite bony union between the autogenous or beef bone pegs and the host bone.

5. Beef bone is a much better substitute for autogenous bone grafts than ivory or cow horn.

REFERENCES

1. Bailey, H. Birmingham M. Rev., 1927, 2: 331.
2. Bogdanovskii, E. Med. Vest., St. Petersb., 1861, 1: 85.
3. Boliarsky, N. N. Vest. khir., 1927, 9: 244.
4. Brenizer, A. G. Surg. Gyn. Obst., 1920, 30: 209.
5. Brooks, B., and Hudson, W. A. Arch. Surg., 1920, 1: 284.
6. Carrell, W. B. Surg. Gyn. Obst., 1936, 63: 636.

7. Cunningham, W. Wisconsin M. J., 1924, 23: 224.
8. Dahl-Iversen, E. Arch. klin. Chir., 1930, 158: 680.
9. Ibid., 1931, 165: 345.
10. Danis, R. Bull. Acad. roy. med. Belgique, 1936, 1: 88.
11. Davison, C., and Christopher, F. Surg. Gyn. Obst., 1924, 38: 534.
12. Fowler, E. B. Illinois M. J., 1934, 65: 56.
13. Ibid., 1934, 66: 231.
14. Gaglio, V. Ann. ital. chir., 1932, 11: 603.
15. Gaudioso, E. T. Policlinico, 1924, 31: 735. Abstr. J. Am. M. Ass., 1924, 83: 227.
16. Gazzotti, L. G. Chir. org. movim., 1923, 7: 311.
17. Harris, I. B. Ohio M. J., 1925, 21: 818.
18. Hendon, G. A. South. M. J., 1925, 18: 801.
19. Henderson, M. S. J. Am. M. Ass., 1920, 74: 715.
20. Lexer, E. W. Deut. Zschr. Chir., 1932, 236: 234.
21. Magnuson, P. B. J. Am. M. Ass., 1913, 61: 1514.
22. Menegaux, G., Moyse, P., and Odiette, D. Presse med., 1934, 42: 658.
23. Ody, F. Lyon chir., 1926, 23: 296.
24. Ruhl, J. Arch. orthop. Unfallchir., 1934, 34: 615.
25. Siegling, J. A., and Fahey, J. J. J. Bone Surg., 1936, 18(n.s.): 439.
26. Tarnowsky, G. de Surg. Gyn. Obst., 1916, 22: 610.,
27. Ibid., 1922, 35: 342.
28. Troell, A. Hygiea, 1923, 85: 79.
29. Werwath, K. Chirurg, 1930, 2: 1126.

CONGENITAL ATRESIA OF THE ESOPHAGUS WITH TRACHEOESOPHAGEAL FISTULA

Extrapleural Ligation of Fistula and End-to-End Anastomosis of Esophageal Segments

CAMERON HAIGHT, M.D., and HARRY A. TOWSLEY, M.D.,
Ann Arbor, Michigan

THE most frequent type of congenital anomaly of the esophagus consists of a blind upper esophageal segment and a lower segment communicating with the trachea. The surgical treatment of this anomaly has until recently been unsuccessful. The reasons for failure are primarily due to the deep location and extent of the anomaly, the technical difficulties encountered in correcting it, and the complications occurring before and after operation.

In the surgical management of congenital atresia of the esophagus associated with tracheoesophageal fistula, two general plans of treatment have been used. One plan, the indirect attack, aims to circumvent the anomaly by the use of staged operations. In principle, the indirect plan consists of (1) a gastrostomy for permanent feedings, (2) ligation or exteriorization of the distal esophageal segment to prevent the regurgitation of gastric contents into the trachea and bronchi, and (3) exteriorization of the upper esophageal segment to allow for drainage of pharyngeal secretions onto the skin. The various methods of application of this plan will be described later in this report. The other plan of attack is the direct one whereby the continuity of the esophagus is restored. The operation consists of a one stage extrapleural exposure of the anomaly with ligation of the tracheoesophageal fistula and simultaneous anastomosis of the two esophageal segments. The advantage of the direct plan is that, if successful, the patient is able to swallow normally.

From the Department of Surgery and the Department of Pediatrics, University of Michigan Medical School, Ann Arbor, Michigan.

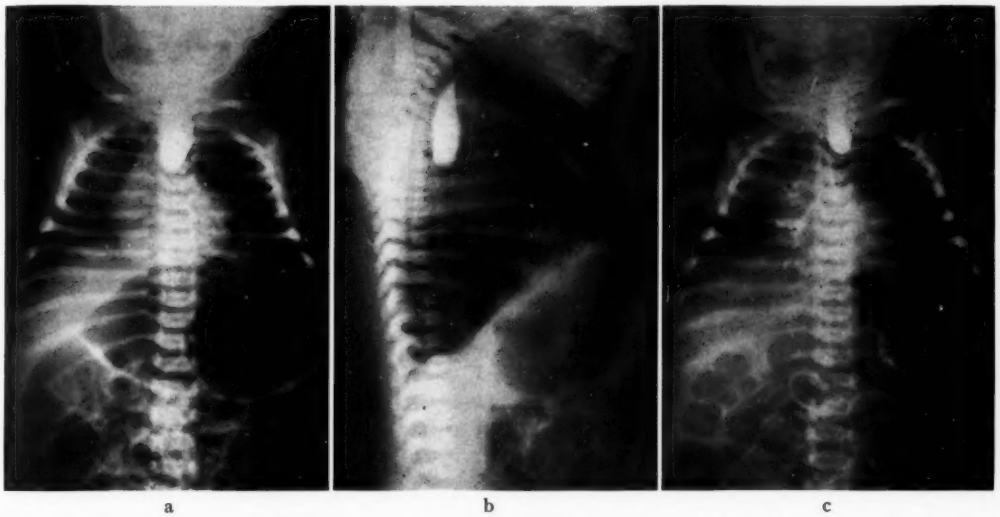
Presented at the Central Surgical Association, Chicago, Illinois, February 27–28, 1942.

During the last 7 years 15 infants with congenital atresia of the esophagus have been admitted to the University of Michigan Hospital. A tracheoesophageal fistula was present in 14 of the 15 cases, the anomaly being of the type 3 B, as described by Vogt. In the remaining case air was not present in the stomach, but the absence of a fistula could not be definitely ascertained, as the patient died without operation or autopsy. This report will be concerned with the experiences encountered in these patients, with particular reference to the findings in 9 patients in whom a thoracic exploration has been done. One case with a successful reconstruction of the esophagus will be reported in detail.

CASE REPORT

J. M., No. 477331, a girl 12 days of age, was admitted to the University Hospital on March 14, 1941. The patient was referred by Dr. Moses Cooperstock of the Northern Michigan Children's Clinic, Marquette, Michigan, with the diagnosis of congenital atresia of the esophagus with tracheoesophageal fistula.

The infant had presented evidences of hemorrhagic disease of the newborn on the day following delivery. Bleeding had occurred from the mouth and rectum, and the obstetrician, Dr. J. H. Fyvie of Manistique, Michigan, had administered vitamin K. Fluid taken by mouth was immediately regurgitated with associated cyanosis. A catheter introduced under roentgenoscopic control could not be passed beyond the junction of the upper and middle thirds of the esophagus. Roentgenograms after the administration of lipiodol by mouth (Fig. 1) revealed an obstruction of the esophagus at the lower portion of the upper third. A large amount of air was noted in the stomach and intestines. A roentgenogram made 1 hour later showed lipiodol within the tracheobronchial tree. A small amount of lipiodol had passed from the trachea through the tracheoesophageal fistula and into the stomach (Figs. 1,c and 2).



a b c

Fig. 1. a and b, Frontal and lateral roentgenograms following the ingestion of lipiodol show the blind dilated upper esophageal segment. The stomach and intestines are distended with air indicating the presence of a tracheoesophageal fistula. c, One hour later. Retained lipiodol is seen in the upper esophageal segment. Some of the lipiodol has overflowed into the trachea and bronchi, and a small amount has entered the stomach by way of the tracheoesophageal fistula (aspiration of the opaque medium by means of a catheter immediately after the film studies were made would probably have prevented the overflow into the trachea). Preadmission roentgenograms were furnished by courtesy of Dr. M. Cooperstock, Marquette, Michigan.

Treatment at the Northern Michigan Children's Clinic consisted of administration of fluids subcutaneously and intravenously. In transporting the patient from Marquette to Ann Arbor, a distance of approximately 500 miles, Dr. Cooperstock arranged with two local physicians en route for the administration of parenteral fluids so that the child would not become too dehydrated during the long automobile trip.

Examination revealed a well developed infant weighing 8 pounds and 4 ounces. The rectal temperature of 103 degrees F. appeared to be the result of moderate dehydration which was evident by the dryness of the mucous membranes of the mouth and tongue. A considerable amount of thick mucus was present in the pharynx. Many loud rhonchi over both lung fields disappeared after aspiration of mucus from the pharynx. No râles were heard and there was no evidence of pneumonia or atelectasis. The heart sounds were of good quality. The abdomen was soft and gastric tympany was present on percussion. As the preadmission roentgenograms were not available, a roentgenologic examination of the anomaly was repeated. A catheter introduced under roentgenoscopic control showed a blind upper esophageal segment extending down to the level of the second dorsal vertebra. A small amount of lipiodol was injected, "spot" films were made, and the lipiodol was then aspirated. The lower level of the upper segment was again noted to be at the second dorsal vertebra. Roentgenograms of the chest and abdomen showed both lung fields to be clear and a large amount of air was seen in the stomach and intestines. In view of the elevated temperature and moderate dehydration, fluids were given to correct the dehydration and operation was deferred. On the following morning, the temperature was normal and the lung fields remained clear, although foamy mucus in the mouth and nose required frequent aspiration. In view of the satisfactory general condition of the infant, it was decided to proceed with operation.

Operation, March 15, 1941. Extrapleural ligation of tracheoesophageal fistula and end-to-end anastomosis of esophageal segments. With the infant lying on the right side a left paravertebral incision was made, under local anesthesia (¼ per cent metycaine hydrochloride solution). Local anesthesia was continued until the anastomosis was begun when general anesthesia was necessary. The posterior portions of the 2d, 3d, 4th, and 5th ribs were resected subperiosteally for a distance of approximately 4 centimeters each. The 2d, 3d, and 4th intercostal nerves were resected, the accompanying intercostal vessels were doubly

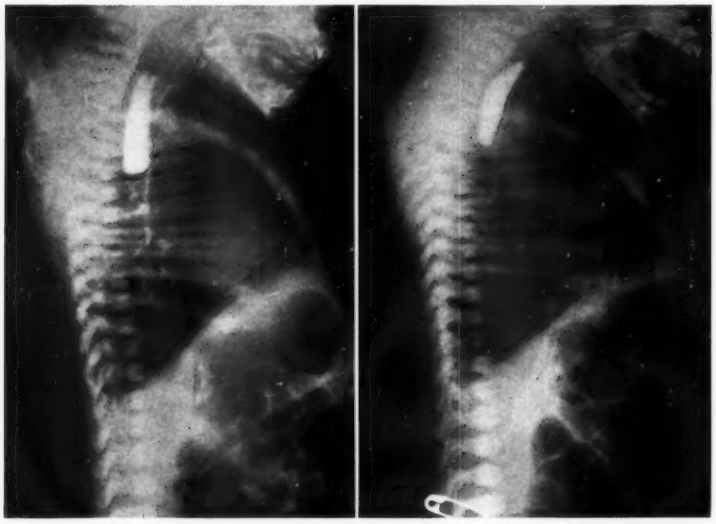


Fig. 2. Mobility of the upper esophageal segment is demonstrated in these lateral roentgenograms 1 and 4 hours after the ingestion of lipiodol. Roentgenoscopic observations confirmed the wide degree of vertical excursion.

ligated and divided, and the intercostal muscles and periosteum were divided (Fig. 3). The costal and mediastinal pleurae were separated from the thoracic wall by blunt dissection, thereby exposing the left subclavian artery extrapleurally. The subclavian artery was displaced forward by an illuminated retractor (Fig. 4). The upper esophageal segment was situated higher than usual, so much so that it could not be seen until it had been pushed downward by a catheter introduced through the mouth. A tension suture was placed in the wall of the upper segment. In order to gain adequate exposure of the lower esophageal segment, the two uppermost intercostal vessels arising from the aorta were doubly ligated and divided, allowing the presenting portion of the aortic arch to be displaced downward, forward and mesially. The lower esophageal segment, measuring about 6 millimeters in diameter, was freed up to its point of communication with the trachea (about 0.5—1 cm. above the bifurcation). It was ligated with silk close to the trachea and was divided distal to the ligature. Traction on the tension suture allowed the blind upper pouch to be drawn down to the level of the distal segment, but when the patient strained or cried, the upper segment retracted upward into the neck and out of sight. The tip of the upper segment was opened for a distance corresponding to the diameter of the distal segment and the interior of the two segments was cleansed with a 1:3000 solution of acriflavine. When an attempt was made to unite the two segments, the first suture pulled out due to the forceful upward retraction of the upper segment when the child strained. The tension suture in the upper segment proved to be a fortunate provision, inasmuch as the upper segment again disappeared from view. As it had been opened, it is problematical whether it could have been pushed downward again by a catheter, and an attempt to grasp it would have been a blind maneuver. Open drop ether anesthesia was then begun; the complete relaxation that was obtained allowed the two segments to be approximated without tension. A single layer of interrupted sutures of plastic silk was used to construct the anastomosis. As the mucosa of the upper segment tended to be everted in one place, it was inverted with an additional suture. A small rubber drain was placed near to the site of the anastomosis and

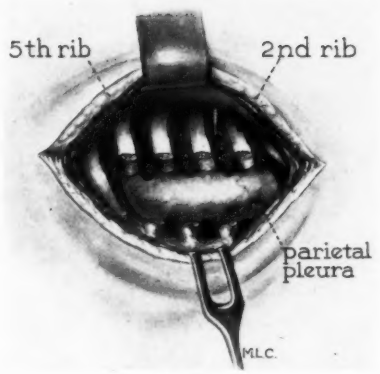


Fig. 3.

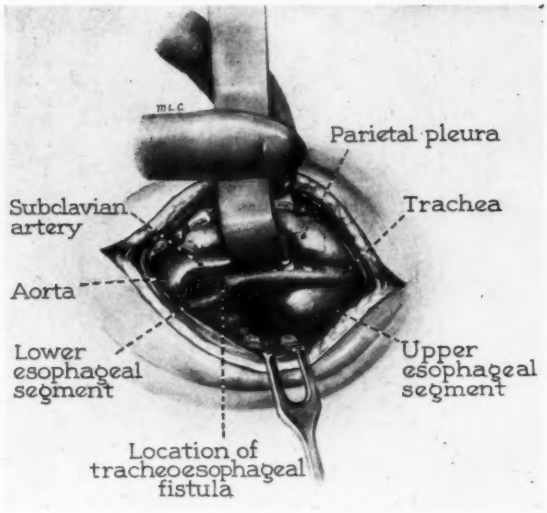


Fig. 4.

Fig. 3. Drawing illustrates the extent of the costal resections. The posterior and posterolateral portions of the 2d, 3d, 4th, and 5th ribs have been resected and the intercostal muscles, vessels, and nerves, and periosteal beds have been divided to expose the parietal pleura.

Fig. 4. Diagrammatic drawing to illustrate the left extrapleural exposure of the anomaly. The parietal pleura has been separated from the thoracic wall. The subclavian artery is being retracted forward, exposing the upper esophageal segment. The uppermost intercostal artery has been ligated and divided to allow the descending portion of the aortic arch to be displaced forward. The origin of the lower esophageal segment is seen. The drawing shows an exposure of the entire operative field, whereas at operation it is possible to obtain an exposure of only a portion of the operative field at any one time.

was brought out through the lower angle of the incision. The wound was closed in layers with interrupted silk sutures. The skin edges were closely approximated around the drain. As an added precaution to prevent the sucking of air into the extrapleural space, a vaseline gauze dressing was applied. Although the parietal pleura was extremely thin, it was not opened at any time during the operation. The infant's condition was good at the end of the operation.

Postoperative course. Upon return to the nursery, the child was cyanotic and the respirations were rapid and slightly labored. An oxygen tent was used for the following 14 days because of the return of cyanosis whenever the infant was removed from the tent. As a prophylactic measure against infection, 0.25 grams of sulfathiazole was given every 6 hours by rectum. On the day of the operation, 300 cubic centimeters of normal saline solution was given subcutaneously. Five hundred cubic centimeters of saline solution was given on the 1st postoperative day and 200 cubic centimeters on the 2d day. Edema of the legs and genitalia occurred on the 2d postoperative day. As generalized edema had developed on the 3d day, fluids were withheld. During the first several days following operation, a considerable amount of mucus in the pharynx required aspiration at intervals. Coarse rhonchi were evident at times on auscultation of the chest and an occasional cough was noted. There were no physical signs of bronchopneumonia, and roentgenograms on the first and third days likewise showed no evidence of pneumonia.

On the 4th postoperative day, several drops of sterile water were placed in the infant's mouth every hour while awake. She appeared to be hungry and sucked her fingers much of the time, but she did not choke on the saliva. On the 6th postoperative day, carbon dioxide-oxygen inhalations were started because of persistent cyanosis. Foamy secretions suggestive of saliva were seen around the rubber drain in the operative incision on the seventh postoperative day. The wound showed evidence of infection. A small amount of dilute methylene blue was given by mouth, but the dye could not be seen in the wound or on the dressing. The child was then given a small amount of lipiodol under roentgenoscopic control. The oil passed down to the site of the anastomosis where the column of oil bifurcated and practically all the oil extravasated into the operative wound. Only a small amount of the lipiodol continued down into the distal esophagus.

Fig. 5. Photographs of patient 3 months after closure of tracheoesophageal fistula and end-to-end anastomosis of the esophageal segments. The thoracic wound has been healed for 1 month, and the gastrostomy wound has been healed for 1½ months.

The feedings were discontinued by mouth, and on the 10th postoperative day, a gastrostomy was done by Dr. H. K. Ransom. In the week preceding the gastrostomy the infant received 75 cubic centimeters of plasma on the 4th postoperative day, 75 cubic centimeters of plasma on the 5th postoperative day and 85 cubic centimeters of citrated blood on the 9th postoperative day. Fluids had been continued mostly by subcutaneous saline infusions, supplemented by two intravenous infusions of 10 per cent glucose. On the day following the gastrostomy, the hemoglobin was 56 per cent, the red blood cells, 2,500,000 and the plasma proteins 3.8 per cent, the albumin fraction being 2.5 per cent and the globulin fraction 1.3 per cent. In view of the anemia and low serum proteins, a second transfusion of 80 cubic centimeters of citrated blood was given. A moderate degree of edema persisted for the next few days, but disappeared after 60 cubic centimeters of plasma had been given on the 13th postoperative day.

Feedings by the gastrostomy tube were started on the day following the gastrostomy and consisted of small amounts of 5 per cent glucose every 4 hours, followed shortly by a formula of evaporated milk, Karo syrup and water. The feedings were increased to 2 ounces every 3 hours. Curded milk particles escaped from the thoracic wound 3 days after the gastrostomy feedings were begun. At this time a catheter was introduced by mouth and advanced into the esophagus, in order to determine whether the channel at the site of the anastomosis could be probed, in the hope that a thread could be introduced into the stomach. However, the catheter emerged from the wound in the chest. The gastrostomy feedings were reduced to three-quarters of an ounce every 2 hours, and regurgitation of the feedings into the thoracic wound was thereby prevented. On the 20th day following operation, and on the 10th day following the gastrostomy, the child regurgitated through the mouth approximately one-quarter of an ounce of the formula that had been given by the gastrostomy tube. This finding demonstrated the patency of the lumen of the esophagus. On the following day, lipiodol was again administered by mouth and the opaque medium was seen to pass down to the site of the anastomosis. The lipiodol then deviated to the left and passed downward into the stomach. No lipiodol was seen in the extrapleural wound. From this observation it appeared that the esophageal fistula had become closed by secondary intention healing. The thoracic wound was packed daily with a narrow strip of gauze and was completely healed 2 months after operation.

Feedings by mouth were started on the 21st postoperative day. The child eagerly took 2 cubic centimeters of water every 2 hours by mouth. On the following day the feedings were increased to 5 cubic centimeters of water every 2 hours. Three days later, when the child eructated, gas could be heard gurgling from the infant's mouth. A formula was then started by mouth, and the amount of the feedings was gradually increased. During this period of increased feedings by mouth, the feedings through the gastrostomy tube were simultaneously reduced. Roentgenographic and roentgenoscopic examinations of the esophagus were made with the use of rugar on the 38th postoperative day. The rugar passed down to a point at approximately the junction of the upper and middle thirds of the esophagus where there was temporary hesitation of the opaque mixture. The upper part of the esophagus was moderately dilated. The patient was then fed a small amount of formula and as the milk mixed with the rugar, the mixture ran down into the distal esophagus. A marked narrowing was present at the site of the anastomosis where the lumen of the esophagus deviated to the left and posteriorly. There was, however, no evidence of leakage. Roentgenograms were made immediately following the fluoroscopic observation, and all the opaque mixture had passed into the stomach at the time the films were made. The gastrostomy feedings were discontinued on the 39th day as the infant was able to take all the necessary feedings by mouth. The gastrostomy tube was removed on the 42d postoperative day, and the gastrostomy wound was completely healed 1 week later (Fig. 5).

The infant's weight decreased from 8 pounds and 4 ounces on admission to a minimum of 7 pounds and 12 ounces during the 4th week of hospitalization. During the 5th week, the weight began to increase

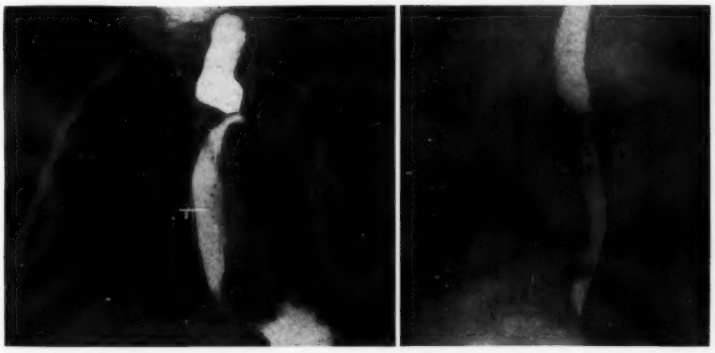


Fig. 6. Roentgenographic examination following the ingestion of rugar 4 months after operation. The upper portion of the esophagus is moderately dilated, and a short narrow stricture is present at the site of the anastomosis as a result of healing by second intention. The lumen of the esophagus in the region of the stricture has a pronounced cork-screw curve, as seen in the frontal projection.

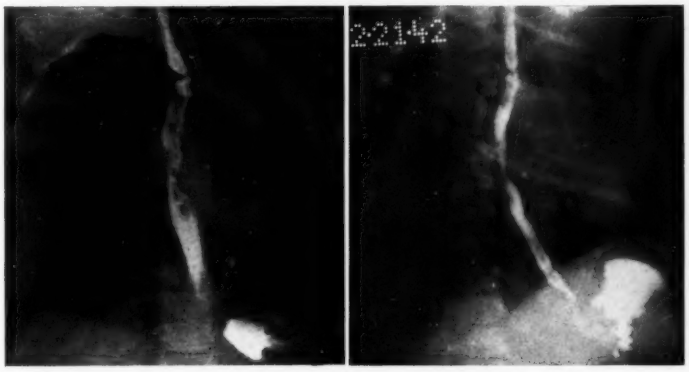


Fig. 7. Roentgenographic examination 11¼ months after operation. There is no dilatation of the upper portion of the esophagus. The lumen of the esophagus at the level of the stricture is larger than in Figure 6 and is considerably less curved.

and at 6 months, the infant weighed 12 pounds and 2 ounces. At 11½ months, the time of this report, the weight is 17 pounds. During the 3d and 4th months after operation, the feedings consisted of a formula of evaporated milk, 50 per cent Karo syrup and water. During the 5th month, cereal (Pablum) was started by mouth and has been continued to date. The patient is now receiving a cooked cereal twice daily in addition to strained vegetables and fruits.

The feedings have often been accompanied by an accumulation of mucus in the pharynx and upper esophagus, the mucus interfering greatly with the ability to swallow. These episodes occur several times weekly at irregular intervals and persist during an entire feeding. Usually at the succeeding feeding, the mucus is not noticed, but the tendency for mucus accumulations is strikingly increased during an upper respiratory infection. To counteract this tendency, the infant has been given small sips of water prior to each feeding with beneficial effects. For a period of several months atropine sulfate (1 drop of a 1:2000 solution) was given twice daily to dry up the pharyngeal secretions. The atropine sulfate proved helpful at first, but later it became less effectual and was discontinued. The episodes of mucus accumulation are becoming less frequent, although, when present, they occur at each feeding during an entire day. Repeated roentgenoscopic and roentgenographic observations have shown a persistence of the stricture at the site of the anastomosis (Fig. 6), but the more recent observations show less delay in the passage of the opaque meal at the site of the stricture. Likewise there has been a gradual decrease in the degree of dilatation of the esophagus above the stricture and at the present

Fig. 8. Photograph of patient 11¼ months after operation.

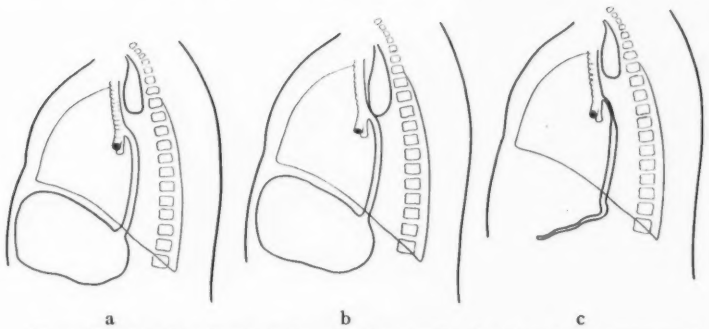
time, there is no widening of the upper esophagus (Fig. 7). The stricture, however, is sufficiently tight so that it is believed that subsequent dilatation will be advisable.[1]

PREOPERATIVE CONSIDERATIONS

Diagnosis. The presence of esophageal obstruction is readily suspected from the typical history of inability to swallow fluids and of attacks of choking, dyspnea, and cyanosis during the attempted ingestion of fluids. Examination reveals intermittent accumulations of considerable mucus in the pharynx. The respirations may be partially obstructed when excessive amounts of secretions are present in the pharynx, or if secretions have gained entrance into the tracheobronchial tree. A positive diagnosis of esophageal obstruction is made by roentgenologic examination with an opaque medium or by the inability to pass a catheter into the stomach. In the presence of a complete esophageal obstruction, the existence of a tracheoesophageal fistula is indicated by the presence of tympany or distention of the upper abdomen on physical examination and by the visualization of air in the stomach on roentgenologic examination. The diagnosis of atresia of the esophagus with tracheoesophageal fistula can also be made by endoscopic examination of the esophagus and trachea, as performed by Tucker and Pendergrass, and Shaw (14). Shaw also employed endoscopy for the removal of retained barium in the tracheobronchial tree and in the upper esophageal segment. Shaw advises that preoperative bronchoscopic examination be done in all cases to determine the type of anomaly, but to date we believe that bronchoscopy is not necessary to establish the diagnosis except possibly in those cases without air in the stomach. Also, we have not employed bronchoscopic examination as we have felt that it carries certain risks in newborn infants.

Roentgenographic observations concerning operability. A liquid radio-opaque material is used to determine the level of obstruction of the upper esophageal segment. Iodized oil should be employed instead of a barium suspension, as the barium may cause serious pulmonary complications if it gains entrance into the bronchi. The iodized oil is administered under roentgenoscopic control, as it is advisable to limit the amount of oil so that it will not overflow into the trachea. At the conclusion of the roentgen examination, the retained oil in the upper esophageal segment is aspirated through a catheter that is introduced for this purpose. The blind end of the dilated upper esophageal segment is usually found at a level between the 1st and 3d dorsal vertebrae. As seen fluoroscopically, the upper esophageal segment is not a fixed structure, but undergoes a vertical excursion during respiration. During inspiration the upper segment descends to a lower level than on expiration. The amplitude of the excursion is augmented by crying and deep breathing, and may be as much as the height of 2 dorsal vertebrae. Roentgenoscopic examination furnishes a more accurate means of determining the length of the upper segment than does

[1]May 7, 1943. The intermittent episodes of accumulation of mucus and regurgitation of food at intervals of 7 to 14 days have continued to occur. Because of these symptoms, an esophagoscopic examination was done by Dr. J. H. Maxwell on August 18, 1942 (17 months after operation). The examination revealed an epithelialized, elliptical stenosis at the site of the anastomosis. The stenosis was readily dilated with bougies. On roentgenoscopic examination 5 weeks later, rugar passed through the constricted area without difficulty. Accordingly the esophagoscopic dilatation has not been repeated. The weight was 22 pounds at the time the patient was discharged from the hospital on December 28, 1942. The patient was examined at the Northern Michigan Children's Clinic on April 21, 1943. The child was in good general condition and had been enjoying normal activities. Although the regurgitation of food at intervals had continued, the weight had increased to 23 pounds. Lipiodol was administered by mouth, and on roentgenoscopic examination the oil passed through the esophagus without delay. The esophagus deviated to the left at the site of the anastomosis, but the tight stricture that had been present in the earlier films was not seen.



a b c

Fig. 9. The drawings illustrate the type of anomalies that have been encountered in 8 of the 15 cases in which the diameter of the lower segment could be determined at operation. a, Air is present in the stomach indicating the presence of a tracheoesophageal fistula. The two esophageal segments are separated from one another, but the diameter of the lower segment is ample for an anastomosis. Three cases. b, Same as drawing a, except that partial muscular continuity exists between the two segments. Two cases. c, The lower segment is contracted for a variable distance below its attachment to the trachea. Three cases. In 2 of these cases air was not present in the stomach (as illustrated). In 1 of the 2 cases the lower segment was too narrow to permit an anastomosis to be made; in the other case an anastomosis was possible after dilatation of the contracted lower segment during operation (see Fig. 10). In the third case, the stomach was distended with air (not illustrated), but the diameter of the lower segment was too narrow for an anastomosis.

roentgenographic examination. If one considers the possiblity of operative correction from a study of the films alone, the fact that the upper segment occupies a high position, as seen in the films, is not necessarily a contraindication to surgical reconstruction. Thus in one of our cases, the roentgenograms revealed the upper segment to be situated higher than usual. It apparently extended only as low as the 1st dorsal vertebra. At operation, however, the upper segment was found to extend even lower than usual. In this case, the tip of the upper segment overlapped the lower segment at a level slightly above the bifurcation of the trachea, and the two segments were attached to one another by a partial continuity of their muscle coats. This partial continuity of the musculature of the two segments has been noted in another of the 9 cases that have been surgically explored. In the latter instance the upper segment had a low position (4th dorsal), as seen in the preoperative roentgenograms.

The presence of air in the stomach is indicative of a communication between the trachea and the lower esophageal segment. Although the failure to visualize air in the stomach suggests the absence of a tracheoesophageal fistula, this fact is not necessarily true. In 2 of the 3 cases in which air was not seen in the stomach by roentgenologic examination (Cases 12, 14, and 15), an unusually small communication was found to exist between the trachea and a narrow lower esophagus at operation. After dilatation of the greatly contracted lower segment during operation in 1 of the 2 cases (Case 12), it was possible to perform a technically satisfactory anastomosis (Fig. 10) between the two segments. In the other case (Case 15) the lower segment was too small to allow dilatation, and no attempt was made to perform an anastomosis. In the 3d case (Case 14) the exact findings are not known as the infant died without operation and an autopsy was refused.

Time of operation. The operative correction of a tracheoesophageal fistula is not a procedure of the utmost emergency. The time at which the operation is undertaken is of secondary importance to the general condition of the patient. The operation should not be delayed unnecessarily, inasmuch as the earlier it is done, the shorter is the opportunity for the development of pneumonia from the aspiration of pharyngeal secretions. It is advisable, however, that the operation should

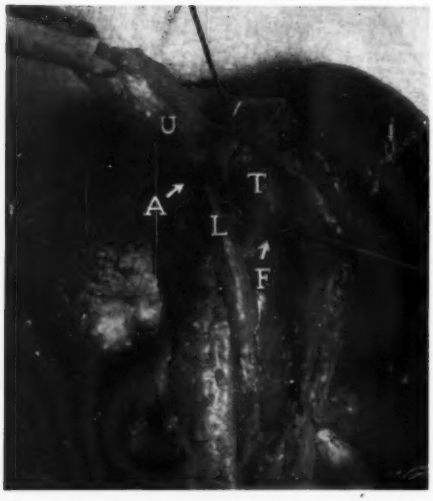


Fig. 10. Autopsy specimen (Case 12), posterior view of thoracic organs removed *en masse*. Death occurred 12 hours after ligation of the fistulous communication with the right main bronchus, and anastomosis of the two esophageal segments. In this case air was not present in the stomach before operation. At operation an abnormally small distal segment, arising from the right main bronchus one millimeter below the carina, gradually enlarged to normal size 2.5 centimeters below the bifurcation of the trachea. Dilatation of the contracted lower segment with ureteral and urethral catheters was necessary before the anastomosis could be made *U*, upper esophagus; *L*, lower esophagus; *T*, trachea; arrow *A*, anastomosis; arrow *F*, fistula ligated at its origin from right main bronchus.

be deferred until ample time has been allowed to get the infant into the best possible condition. A period of usually at least 1 day, and occasionally several days, is required to accomplish this objective. If fever is present, the cause of the fever should be corrected before operation.

The preoperative general condition of the patient. In the preoperative evaluation of the operability of the patient, the important complicating factors that have been observed in the 15 patients in this series have been prematurity, bronchopneumonia and atelectasis, other congenital anomalies, and dehydration. As prematurity offers an added obstacle to success, the possibility of prematurity should be considered in relation to the size of the infant. Five of the 15 patients whom we have observed have been premature by more than 2 weeks. Operative intervention was contraindicated in 3 of the premature infants, although in 1 of these patients, whose death occurred within 24 hours following birth, the diagnosis was not made until autopsy.

Atelectasis and lobular pneumonia have been the most frequent associated pathological conditions, as well as the most frequent causes of death. As these complications may be present at the time the patient is referred for surgical treatment, especial attention should be directed toward evaluation of the pulmonary status before operation. Secretions within the bronchial tree may produce abnormal physical findings that are difficult to distinguish from those occurring in the presence of small areas of lobular pneumonia. When prompt clearing of abnormal signs follows postural treatment, the evidence is in favor of the signs being caused by obstructing bronchial secretions rather than by pneumonia. Roentgen examination is also of value in the differentiation. Atelectasis, when present, has occurred most often in the right upper lobe.

Prophylactic measures which are useful in preventing the overflow of pharyngeal secretions into the trachea are the prone position of the patient, elevation of the foot of the bed and periodic aspiration of the pharynx with a catheter. When bronchial secretions are evident on physical examination, their removal should be accomplished by posture combined with pharyngeal suction, the latter being directed toward stimulation of the cough mechanism. Should these measures fail, bronchoscopy may be indicated. Recently, we have also employed one of the sulfonamide drugs as a prophylactic measure before operation as well as after operation. If pneumonia has already developed, the above measures should be employed in conjunction with any further measures that might be advisable, and operation should not be undertaken until the pulmonary infection has cleared.

The absence or extent of dehydration will depend upon the treatment that the patient has received prior to the time that operation is contemplated. The administration of fluids is more safely accomplished by the subcutaneous route than by the intravenous method. If fluids are administered intravenously, the amount should be regulated with great care so

as to prevent overhydration and pulmonary edema. Pulmonary edema is an important complication which should be avoidable. It was apparently the only cause of death in one of our patients, as well as in one of Lanman's patients. Fluids had been administered intravenously in both of these cases. Pulmonary edema has also been noted as an incidental finding in several of our cases at autopsy. A blood transfusion is a valuable measure to anticipate the blood loss during operation and to prevent or correct depletion of serum proteins.

The anomalies in the 10 cases that have had autopsies have been congenital stricture of the ureter and an anomalous right subclavian artery (arising within the left hemithorax), both occurring in the same patient; pancreatic cysts and talipes cavovalgus in another patient, and extensive fetal atelectasis in a third patient.

Icterus neonatorum has been observed in one of the patients in this series, and vitamin K was accordingly administered before operation. We now believe that vitamin K should be given before operation in all cases, and it is especially indicated if operation is performed between the 3d and 6th days, as the blood level of vitamin K has been shown to be lowest during this period. The use of ascorbic acid is helpful, primarily because of its favorable effect upon wound healing.

OPERATIVE CONSIDERATIONS

Type of operation. The surgically ideal method of attack is one that accomplishes closure of the fistula and simultaneous restoration of the continuity of the esophagus by an anastomosis between the proximal and distal segments. This direct type of operation was suggested by Richter in 1913, but the technical difficulties that would be encountered and the presumed inability of an infant to withstand an intrathoracic procedure of this magnitude have until recently led to the performance of various but, in our opinion, less desirable operations or combinations of operations. In principle, these indirect procedures aim to feed the patient by gastrostomy, to prevent secretions in the upper segment from entering the respiratory tract by a cervical esophagostomy, and finally to prevent regurgitation of gastric contents into the trachea. The latter has been accomplished in several ways. The first attempts were by Richter (1913) who ligated the lower esophageal segment at its junction with the trachea by means of a right transpleural thoracotomy followed by a gastrostomy. C. G. Mixter (1929) employed a posterior extrapleural approach with ligation of the fistula and exteriorization of the proximal end of the lower segment by bringing it to the surface of the incision. Another plan has been to interrupt the lower segment through an abdominal approach combined with a gastrostomy. Ligation of the lower end of the esophagus at its junction with the stomach has been described by Smith (1923), Rosenthal and Himmelstein (1932), Tucker and Pendergrass (1933) and Gage and Ochsner (1936). Scott employed the same principle by transection of the cardiac portion of the stomach. In his first patient (1928) Scott brought the upper end of the gastric incision to the skin surface to form an abdominal "esophagostomy." The lower end of the gastric incision was closed and a gastrostomy was done. This plan has also been used by Gamble. In his second patient (1934) Scott closed both ends of the gastric incision and performed a gastrostomy. Leven (6), in 1936, recommended exteriorization of the lower esophagus and cardiac portion of the stomach. He produced an angulation and obstruction of the exteriorized segment by passing a rubber tube beneath it. A gastrostomy was made distal to the angulation.

Carter (1941) advocated a preliminary cervical esophagostomy followed by a high intramediastinal ligation of the lower esophageal segment through an abdominal approach. The lower esophagus was divided distal to the ligature, and the portion of the esophagus attached to the stomach was brought out as a "gastrostomy tube." A disadvantage of the techniques that interrupt the continuity of the lower segment through an abdominal approach is that secretions within this segment must drain into the trachea, although in Carter's case there was no evidence that esophageal secretions had entered the bronchial tree.

Leven (7), in 1941, in his most recent article advised interruption of the distal esophagus by a direct extrapleural attack upon the fistulous communication with the trachea instead of interruption of the lower esophagus at its junction with the stomach, inasmuch as the obstruction of the esophagus at its lower level does not allow for drainage from the lower segment except into the trachea. In his most recent patient, he performed a 3 stage procedure. At the first stage (November, 1939) a preliminary gastrostomy was made. After recovery from this operation, the communication with the trachea was ligated extrapleurally. At the third stage, the upper esophagus was mobilized and brought to the skin surface to form a cervical esophagostomy. The patient who was alive and well 18 months following the first operation is the only successful case to date by the indirect approach. Leven expects, at some future time, to construct an antethoracic esophagus to establish the continuity of the gastrointestinal tract.

The main disadvantage of the indirect procedures is that they do not attack the problem directly and that the infant is still unable to swallow unless an antethoracic esophagus is constructed by a skin-lined tube or unless the cervical esophagostomy and the gastrostomy are connected with a rubber tube. The indirect type of operation, however, is recommended by Leven and Carter as offering a safer approach to the problem than does a single stage extrapleural reconstruction of the esophagus. Carter also believes that his method provides an ideal type of gastrostomy tube and that the distance between the two esophageal stomas is short so that they could be readily joined by a skin tube.

The direct operation with extrapleural closure of the fistula and simultaneous primary anastomosis of the esophageal segments is favored by Shaw (14), Samson, Lanman, and the authors, provided the anomaly is such that an anastomosis is possible. Our experience in a small number of cases suggests that this type of operation can be done in most instances. The first reported operation of this type was described by Shaw (14) in 1939, who also quotes a personal communication from Samson describing a case in which the same technique was employed. Lanman, in 1940, subsequently has reported 4 patients operated on by this technique in 1936 and 1937. It is believed that the first of Lanman's cases represents the first application of the principle of extrapleural closure of the fistula combined with primary anastomosis of the two segments of the esophagus. Although all of these patients died, unfortunate circumstances contributed to the death of 2 of the patients. In one of Lanman's patients who lived 9 days, postmortem examination suggested that death was due solely to overhydration with fluids administered by a continuous intravenous infusion. There was no leakage of the anastomosis, and cultures of the wound showed no growth. Shaw's patient died of a transfusion reaction on the 12th postoperative day. The esophageal anastomosis had been made over a No. 8 F. catheter. Postmortem examination showed that the anastomosed esophageal segments had separated for a distance of 13 millimeters, and the catheter could be seen lying in a nonepithelized tract consisting of granulation tissue. The esophageal opening into the trachea was closed, and the stump was buried in granulation tissue. There was an extensive bilateral pneumonia, and two bronchiectatic abscesses were present in the left lower lobe.

In a recent personal communication Shaw (15) mentions a successful case of reconstruction of the esophagus by the direct operation. The patient, who was 7 months of age at the time of Shaw's communication, was operated upon subsequent to the patient presented in this article. Shaw performed a gastrostomy on the 5th day following correction of the anomaly, as difficulties were encountered in feeding the patient by mouth. The gastrostomy also allowed retrograde dilatations of the esophagus to be done at frequent intervals.

Our interest in the direct method of attack was stimulated by a personal communication from Shaw (13) in 1938 describing his first case. Prior to our knowledge of this case, 3 patients had been operated on in this hospital; in 2, a gastrostomy was performed, and in the 3d case, the cardiac portion of the stomach was ligated and a gastrostomy was made. A

4th case, a premature infant, was not operated upon, as the patient died 27 hours after birth, and diagnosis was not made until postmortem.

In the period of 3½ years since Shaw's communication in 1938, 11 patients have been admitted to the University of Michigan Hospital with congenital atresia of the esophagus, a tracheoesophageal fistula being present in all except possibly 1 case. Two patients were not operated on because of prematurity and poor general condition, and both patients died within 24 hours after admission. In 7 of the 9 remaining cases, for whom an intrathoracic exploration was performed, operation was done with the intention of establishing continuity of the esophagus. Ligation of the fistula and an anastomosis of the esophageal segments were accomplished in 5 cases, and was successful in 1 case. The 2 cases for which an anastomosis was not contemplated are as follows: (1) the extrapleural operation in Case 7 was limited to ligation of the fistulous communication, and a gastrostomy was done for feeding. The anatomical findings, i.e., a normal size lower segment with an overlap of the two segments, were ideal for the performance of an anastomosis, but it was not attempted because of the discouragement resulting from the death of the 2 preceding cases in which an anastomosis had been done; (2) a gastrostomy was done in Case 15 as no air was present in the stomach. The gastrostomy feedings were regurgitated into the trachea, thereby demonstrating the patency of the lower segment. An extrapleural exploration of the anomaly was undertaken. The diameter of the contracted lower segment was too narrow to permit an anastomosis to be made, and the lower segment was ligated. We now believe that an extrapleural operation should be done as the primary operation, even when air is not present in the stomach, as an exploratory operation furnishes the deciding information that is necessary to determine whether an anastomosis is possible or whether the distal segment should be ligated and a gastrostomy done. The findings and method of treatment of the 15 cases observed in this hospital are charted in Table I. The result in all cases has been fatal except in the one described in detail in this report.

Anesthesia. Provision should be made in advance of operation for the administration of positive pressure by the anesthetic gases or oxygen in the event that the pleural cavity is inadvertently opened. A face mask of sufficiently small size to fit air-tight over the infant's mouth and nose should be available for this purpose. Local anesthesia with ¼ per cent metycaine hydrochloride is used until separation of the parietal pleura is begun, when light ether anesthesia by the drop method is started. If the extrapleural separation is done under local anesthesia, the straining of the infant may cause a tear of the parietal pleura by forcing it against the exposed ends of the ribs laterally. Quiet breathing obtained by general anesthesia enables the exposure of the mediastinum with an illuminated, spatula type of retractor to be maintained more easily than when local anesthesia alone is used. The absence of crying and straining is essential in allowing the anastomosis to be made satisfactorily. The advantage of ether anesthesia is particularly well illustrated in the case described in this article. During an attempt to perform the anastomosis under local anesthesia, the two esophageal ends were pulled widely apart whenever the infant strained or attempted to swallow. After satisfactory relaxation had been obtained with ether anesthesia, the esophageal ends were readily approximated without tension upon the suture line.

Technique. The patient is placed in the lateral position and securely strapped to a frame. Heat is applied with hot water bottles to prevent chilling. A left vertical parascapular incision is made from the level of the second to the seventh ribs. Hemostasis is carefully obtained, as a small total amount of blood loss is relatively great for a newborn infant. The trapezius and rhomboideus major muscles are incised, and the sacrospinalis muscle is retracted mesially. In our earlier cases, short lengths (1 to 2 cm.) of the second to sixth ribs inclusive were resected adjacent to their transverse processes, which were shortened. A perforation of the parietal pleura occurred in at least 1 and possibly 2 cases due to the parietal pleura being forced against the lateral ends of the ribs during straining, and in spite

TABLE I.—ANALYSIS OF 15 CASES

Case and Year	Operation—days after birth	Died—after operation	Operation	Air in stomach before operation	Pneumothorax during operation	Anomaly favorable for anastomosis	Remarks
Case 1* B.G.F. 1935	3 days	22 hrs.	Gastrostomy	Yes	——	?¶	Premature (8 mos.) Aspiration pneumonia
Case 2† R.B.: 1936	4 days	18 hrs.	Gastrostomy and ligation of cardiac end of esophagus	Yes	——	?¶	Aspiration pneumonia. Atelectasis
Case 3* B.B.C. 1937	4 days	5½ days	Gastrostomy	Yes	——	?¶	Premature (8–8½ mos.) Aspiration pneumonia
Case 4 B.B.S. 1937	No operation	27 hrs. after birth	None	(No x-ray)	——	?¶	Premature (7½ mos.) Atresia of esophagus not diagnosed until autopsy
Case 5 B.B.O. 1939	3 days	17 hrs.	Left extrapleural suture of fistula. Anastomosis of esophageal segments over T-tube	Yes	Yes	Yes	Upper esophageal segment adherent to and overlapped lower segment. Death due to atelectasis
Case 6‡ C.A.B. 1939	7 days	Died during operation	Right intrapleural ligation of fistula. Anastomosis of esophageal segments over T-tube	Yes	Yes (intentional)	Yes	Respirations became progressively more difficult and shallow after pleural cavity was opened
Case 7 G.P. 1940	11 days	3 days	Left extrapleural ligation of fistula. Anastomosis not attempted. Gastrostomy	Yes	No	Yes	Upper esophageal segment adherent to and overlapped lower segment. Death due to overhydration
Case 8‡ M.W. 1940	3 days	Died during operation	Right extrapleural exploration. Distal segment not found	Yes	Yes	No Autopsy	Operation complicated by bilateral pneumothorax and injury to aorta
Case 9 P.C. 1941	2½ days	3 days	Left extrapleural ligation of fistula. Anastomosis over catheter. Parietal pleura torn, necessitating air-tight drainage of pleural cavity	Yes	Yes	Yes	Overlap of esophageal segments present at operation. Death due to sepsis
Case 10 J.M.: 1941 Reported in detail	13 days	Living	Left extrapleural ligation of fistula. Anastomosis of esophageal segments	Yes	No	Yes	Patient living 11½ mos. after operation
Case 11 G.W.: 1941	No operation	Died 5 days after birth, 1 day after admission	None	Yes	No operation	No Autopsy	Atelectasis present on admission. Condition too poor to permit operation. Atresia of esophagus and air in stomach on x-ray examination. Premature
Case 12 R.W. 1941	6 days	12 hrs.	Left extrapleural ligation of fistula. Anastomosis of esophageal segments	No	No	No	No air in stomach. Abnormally small distal segment arising from right main bronchus, enlarging to normal size 2½ cm. below bifurcation of trachea. Open tracheoesophageal fistula found at operation. Anastomosis intact at autopsy. Lobular pneumonia and atelectasis.
Case 13 S.M. 1942	7 days	6 days	Left extrapleural exploration. Anastomosis not possible because of contracted lower segment	Yes	Yes (bilateral)	No	Abnormally small distal segment arising from trachea. Operation terminated without ligation of distal segment because of poor condition. Death due to hemorrhage from acute ulceration of lower end of esophagus
Case 14 J.T. 1942	No operation	Died 6 days after birth, 1 day after admission	None	No	No operation	No Autopsy	Poor condition of patient prevented operation. Premature
Case 15 P.G. 1942	Gastrostomy 6 days after birth. Ligation of fistula 15 days after birth	Died 15 days after ligation of fistula	Gastrostomy because of absence of air in stomach. Subsequent left extrapleural ligation of fistula because of eructation of gastric feedings	No	No	No	Ligation of fistula deferred until 15 days after birth because of atelectasis following gastrostomy. Anastomosis not attempted because of abnormally small distal segment. Death due to hemorrhage from umbilical vein in ligamentum teres at site of gastrostomy

(*) Operation by Dr. Frederick A. Coller.
(†) Operation by Dr. Henry K. Ransom.
(‡) Operation by Dr. John Alexander.
(¶) The autopsy protocols in Cases 1–4 do not mention the diameter of the lower segment.

May 7, 1943. Since the presentation of this report, 9 additional infants with congenital atresia of the esophagus and tracheoesophageal fistula have been treated. Operation was not performed for one premature infant in poor condition who died on the day after admission. Extrapleural ligation of the fistula and end-to-end anastomosis of the esophageal segments were done in 8 patients. Three of the 8 patients died following repair of the anomaly and 1 patient died following a subsequent gastrostomy. The remaining 4 patients are living 7¾, 3, 1¼, and 1 months, respectively. Primary healing of the anastomosis without the development of a stenosis has occurred in the patient now living 3 months. In this case a gastrostomy was not done. In the 3 remaining surviving patients, leakage of the anastomosis has required a gastrostomy. In 1 of the patients, now living 7¾ months, the extrapleural drain was inadvertently removed on the 1st postoperative day. Primary healing of the wound occurred, but subsequent leakage at the site of the anastomosis resulted in the redevelopment of a tracheoesophageal fistula which is still present. In the patients now living 1¼ and 1 months, respectively, the external esophageal fistula is closing slowly, and it is hoped that spontaneous closure will occur. A right extrapleural approach has been satisfactorily employed in the 3 most recent cases, and it appears to give a better exposure of the distal esophageal segment than does the left extrapleural approach.

of the fact that the rib ends had been made smooth in order to lessen the chance of this complication. We now resect longer lengths (4 to 5 cm.) of the second to fifth ribs inclusive, removing the ribs back to their transverse processes. In the last 5 cases perforation of the pleura has occurred in only 1 case. The importance of avoiding an opening of the parietal pleura cannot be overstressed. In the one patient for whom an intrapleural operation was intentionally done, and in another patient in whom the parietal pleura was torn during operation, the complication of a pneumothorax, even though controlled by positive pressure, added greatly to the respiratory embarrassment during the operation and was a contributory cause of death. An opening of the parietal pleura is particularly serious in infants because the respiratory reserve is only slightly greater than the tidal air requirements. In another patient in whom the parietal pleura was torn during operation, air-tight drainage of the pleural cavity was required at the conclusion of the operation because the pleural rent could not be satisfactorily sutured.

The intercostal muscles and nerves are next divided and the intercostal vessels are doubly ligated and divided. As the parietal pleura can be injured easily during this part of the operation, the periosteum is incised vertically after it has been separated from the parietal pleura. The extrapleural separation is carried out slowly with a small blunt dissector. An illuminated retractor is useful in maintaining the exposure. The parietal pleura is freed out of the costovertebral gutter until the posterior mediastinum is reached. One or more branches of the highest intercostal vein may need to be ligated and divided in order to expose the posterior mediastinum. The left subclavian artery is retracted forward and to the right by the illuminated retractor.

The blind upper end of the esophagus is usually readily found in the upper portion of the posterior mediastinum. It is recognized by the distinctive color and the vertical direction of its external musculature. The diameter of the upper segment is usually about 1.5 centimeters. If the upper segment is not identified promptly, a catheter should be introduced by mouth and advanced until the upper segment can be recognized by palpation of the catheter within it. If the upper segment does not extend down to the level of the operative field, pressure can be made upon the catheter, thereby pushing the upper segment down to a level where it can be found. The tip of the upper segment is secured with a tension suture.

The identification of the lower segment is often more difficult than the identification of the upper segment. In order to gain adequate exposure of the lower segment, the upper one or two intercostal arteries arising from the aorta should be doubly ligated and divided in order to allow the arch of the aorta to be displaced forward and downward. The lower portion of the trachea is identified by palpation of the tracheal cartilages. The diameter of the lower segment, unless contracted, is usually about 6 millimeters or approximately one-half the diameter of the upper segment. When the lower segment arises from the trachea at a distance of 1 to 1.5 centimeters above the carina, recognition of the lower segment is accomplished without difficulty. The longitudinal musculature of the esophagus again aids in identification, although the membranous posterior wall of the trachea possesses a similar appearance which may be misleading.

The separation of the lower segment from the trachea is begun at a point about 1 centimeter below the fistulous communication. A right-angled hemostat with a blunt tip is a convenient instrument for this purpose. The anterior wall of the lower segment is more firmly attached to the posterior wall of the trachea than is the case with the upper segment. The cleavage plane between the lower segment and the trachea may be difficult to develop, although in our cases it has always been possible to do so by blunt dissection. As soon as the instrument has been passed completely around the lower segment, a tape is placed around it in order to provide tension, so that the dissection can then be carried upward to the fistulous communication. The diameter of the lower segment should be carefully estimated. A very narrow lower segment (3 to 4 mm.) may require that an anastomosis should not be attempted, but that the fistula

should be ligated. A gastrostomy and cervical esophagostomy would then be performed at subsequent operations. In our cases a contracted lower segment has been a greater obstacle to the performance of an anastomosis than has the distance of separation of the two segments.

Closure of the fistula is most readily accomplished by a single silk ligature placed around the esophagus and tied as close to the trachea as possible. In one case the lower segment was incised almost flush with the trachea, and the fistulous communication was closed with interrupted sutures of plastic silk. An air-tight closure was not obtained and the closure was a more difficult procedure than when a single ligature had been used. A tension suture is placed in the wall of the distal segment which is then divided close to the ligature. The lumen is cleansed with a mild antiseptic solution. Packing off of the operative wound with gauze has not proved satisfactory because of the limited exposure. The tension suture in the wall of the upper esophagus is held taut, and the blind end is opened to approximately the same diameter as that of the lower segment.

The anastomosis is usually constructed in two layers with interrupted sutures of plastic silk on baby Emmet needles. Approximately 6 or 7 sutures that include all coats of the esophagus are placed in the first row. A second layer of inverting sutures includes only the muscularis and the submucosa. The anastomosis was made over a small T tube in 2 of our cases. In another case, the anastomosis was made over a catheter introduced through the wound, one end being advanced into the upper segment and brought out through the mouth, and the other end advanced into the stomach. When a T tube is used, the anastomosis is constructed with more difficulty than without the tube. The anastomosis, however, is more readily done over a catheter than without one. If a catheter is used, it is removed after the anastomosis has been completed, as the presence of a catheter in the esophagus following operation not only causes an increased stimulation of pharyngeal secretions, but also tends to obstruct the esophagus at the site of the anastomosis, thereby allowing the secretions that collect in the upper esophageal segment to spill over into the trachea. Furthermore, it is believed that healing is more satisfactory if a foreign body is not present within the esophageal lumen. A small soft rubber drain is placed in the lower angle of the incision and advanced to the region of the anastomosis, so as to afford drainage in the event that leakage should occur. Closure of the wound is begun by approximating the anterior ends of the intercostal muscles to the under surface of the sacrospinalis muscle. The extracostal wound is closed in layers, the closure being made securely around the drain to prevent the sucking of air into the extrapleural space. The chest should be examined immediately following operation to be certain that a pneumothorax has not resulted from an unrecognized opening in the parietal pleura.

POSTOPERATIVE CONSIDERATIONS

The infant should be kept in a prone position to prevent the gravitation of oral and pharyngeal secretions into the trachea. Elevation of the foot of the bed is desirable for the same reason and also as a measure to counteract operative shock. The body temperature should be recorded immediately after operation. Heat is applied if the temperature is subnormal. A continuous flow of oxygen administered by a tent is routinely employed. Supplementary inhalations of 5 per cent carbon-dioxide and 95 per cent oxygen are used to increase pulmonary ventilation. A blood transfusion is not given immediately after operation unless it is urgently required, as it is preferable that the infant should not be further disturbed by a transfusion until a period of a day or more has elapsed. Codeine in frequent small doses is advisable to keep the infant quiet and to prevent tension being placed upon the anastomosis by crying and straining. Sulfonamide therapy is continued as a prophylactic measure, and a suitable ascorbic acid blood level is maintained by daily injections.

Fluids consisting principally of 5 per cent dextrose are administered by subcutaneous infusion. Care should be exercised to prevent overhydration, and the amount of fluids

should be considerably less than that ordinarily given to a normal infant. Intravenous fluids, unless given in small quantities, tend to cause pulmonary edema and are best avoided. A transfusion of whole blood or plasma should be given as a supportive measure when indicated to prevent the depletion of serum proteins that otherwise would occur. The use of parenteral fluids is continued until an adequate formula can be given by mouth or until it is ascertained that a gastrostomy will be needed because of leakage. Unless there is evidence of leakage, fluids can be started by mouth several days after operation. The feedings should consist at first of a few drops of 5 per cent glucose. If this is tolerated without choking, the amount is rapidly increased to 2 to 4 cubic centimeters at each feeding. A diluted formula of similar amount is then begun, and the feedings are given slowly with a Breck feeder. The amount of the formula, and later its consistency, are constantly increased until a normal formula can be given.

Roentgen examination of the esophagus should precede the administration of fluids by mouth. The initial examination is conveniently carried out with a portable unit and should consist of a roentgenogram made immediately after the administration of a few drops of lipiodol by mouth. Fluoroscopic examination is more important than film studies in determining the condition of the anastomosis, but a fluoroscopic examination should not be undertaken until the infant's general condition permits it to be done safely. As the crying and struggling of the infant during a fluoroscopic examination place tension upon the anastomosis, the initial fluoroscopy should preferably not be attempted until 10 or 12 days after operation. Interval fluoroscopic examinations are particularly indicated in the subsequent management of the case, so as to determine if a probable stricture at the site of the anastomosis will require dilatation.

Should a gastrostomy be elected, it is preferable to defer the operation until a period of at least 4 or 5 days has elapsed after closure of the fistula, to allow the infant to recover from the effects of the first operation. In 1 of our cases, in which the tracheoesophageal fistula was ligated and no attempt was made to perform an anastomosis, a gastrostomy was done immediately at the conclusion of the extrapleural operation. We realize now that the performance of the gastrostomy immediately after the extrapleural operation was inadvisable as it subjected the patient to an unnecessary amount of surgery at one time. The extrapleural drain should not be removed until it is evident that there is no leakage at the site of the anastomosis.

An important cause of death in patients with congenital atresia of the esophagus is bronchopneumonia resulting from a spillover of pharyngeal secretions into the tracheobronchial tree. Accordingly, efforts should be directed toward maintaining the pharynx and tracheobronchial tree constantly free of secretions, and frequent observations should be made to detect the presence of secretions as soon as they occur. Particular attention should be paid to the character of the respirations by listening with a stethescope placed close to the patient's mouth. Intermittent pharyngeal suction is indicated as soon as pharyngeal secretions are evident. The onset of bronchial secretions is first recognized by the presence of rhonchi and wheezes. When the physical signs of bronchial secretions are noted in one lung, hyperventilation with carbon dioxide-oxygen inhalations should be administered with the patient lying on the contralateral side. Should the secretions persist, an effort should be made to dislodge them by crying or by coughing, the latter being induced by the application of pharyngeal suction with an aspirating catheter. In the event that bronchial secretions cannot be cleared by these measures, bronchoscopy may be needed for aspiration of the secretions. As an early atelectasis or bronchopneumonia may escape clinical recognition, the chest should also be examined by roentgenograms at daily intervals during the first several postoperative days. Furthermore, a pleural effusion of sufficient amount to require thoracentesis may occur on the operative side as a result of the extrapleural operation. The amount of the fluid can best be determined by roentgenograms.

SUMMARY

The surgically ideal plan for the correction of congenital atresia of the esophagus with tracheoesophageal fistula is a reconstruction of the continuity of the esophagus by an extrapleural ligation of the fistula and an end-to-end anastomosis of the esophageal segments. The first successful case of reconstruction of the esophagus by this plan is presented. The factors pertaining to operative correction of the anomaly and experiences in a series of 15 cases are discussed.

REFERENCES

1. Carter, B. N. Surg. Gyn. Obst., 1941, 73: 485–491.
2. Gage, M., and Ochsner, A. Ann. Surg., 1936, 103: 725–737.
3. Gamble, H. A. Ann. Surg., 1938, 107: 701–707.
4. Heatly, C. A. Ann. Otol. Rhin. & Laryng., 1936, 45: 1122–1132.
5. Lanman, T. H. Arch. Surg., 1940, 41: 1060–1083.
6. Leven, N. L. J. Thoracic Surg., 1936, 6: 30–39.
7. Ibid. 1941, 10: 648–657.
8. Mixter, C. G. Discussion of article by Gage and Ochsner.
9. Richter, H. M. Surg. Gyn. Obst., 1913, 17: 397–, 402.
10. Rosenthal, A. H., and Himmelstein, U. Arch. Ped., 1932, 49: 444–462.
11. Samson, P. C. Quoted by Shaw.
12. Scott, W. J. M. Quoted by Heatly.
13. Shaw, R. C. Personal communication to Dr. John Alexander, October 2, 1938.
14. Idem. J. Thoracic Surg., 1939, 9: 213–219.
15. Idem. Personal communication, February 19, 1942.
16. Smith, E. D. Am. J. Surg., 1923, 37: 157–158.
17. Tucker, G., and Pendergrass, E. P. J. Am. M. Ass., 1933, 101: 1726–1727.
18. Vogt, E. C. Am. J. Roentgenol., 1929, 22: 463–465.

TRAUMATIC PERITONITIS: CHOICE OF ROUTES FOR ADMINISTRATION OF SULFONAMIDES

RICHARD K. GILCHRIST, M.D., FRANCIS H. STRAUS, M.D., F.A.C.S., RUSSELL HANSELMAN, M.D., CECIL C. DRAA, M.D., STANLEY E. LAWTON, M.D., F.A.C.S., and MILNOR FREELAND, Ph.D., Chicago, Illinois

IN World War I, the mortality rate (10) in patients reaching the operating room with a perforation of an abdominal viscus was 50 per cent or more. Early deaths were due to hemorrhage and shock. In those dying a few hours later, peritonitis played a major rôle.

During the past few years a marked change has taken place in the treatment of infections, namely, the use of chemotherapy in the form of sulfonamide drugs. In pneumonia, the frequency of parenteral sulfonamide dosage necessary to maintain adequate blood concentration is well understood. While most surgeons use one or another of the sulfonamide drugs when dealing with a potential peritoneal contamination or an established peritonitis, it seems to us that the attainment of an adequate concentration over a period of time is not clearly understood. Certainly with the necessity for treating a great number of perforating injuries of the abdomen in war, the several methods for rapid establishment of an adequate intraperitoneal concentration of one of these drugs, and of equal importance, the necessity of maintaining it, should be understood by all.

Saduck, Black, and Seymour gave 4 grams (0.06 per kilogram) of sulfathiazole per os to adults and found that the maximum concentration in the blood was reached after 3 hours and that it had fallen off greatly after 6 hours. Haag and his co-workers have shown that in dogs it takes 2 to 4 hours to reach maximum blood concentration after oral administration of sulfanilamide, sulfathiazole, and sulfapyridine, and this level is maintained for 2 to 4 hours. With a dose of 100 milligrams per kilogram of sulfathiazole, on an empty stomach and without peritonitis, they found that the blood concentration reached 4 milligrams per cent after 3 hours and maintained this level for 3 hours before falling. This dose would be equivalent to 6.8 grams in a 150 pound man. Long advises the oral administration of 2 to 4 grams of sulfanilamide at the time of an injury. We understand that the Army recommends 6 grams by mouth.

In early peritonitis, we shall show the time necessary to establish adequate blood and intraperitoneal concentration of various sulfonamides after administration by mouth, intravenous injection, implantation of crystals into the abdomen, and injection of sulfonamides intraperitoneally. In our experiments we produced peritonitis in 75 dogs; 716 determinations of sulfonamide concentrations in heart blood and peritoneal fluid were made.

Sulfanilamide by mouth in early peritonitis did not produce adequate blood and peritoneal fluid concentrations in dogs. Under sodium nembutal anesthesia, we made a 1 centimeter transverse incision in the colon of dogs and dropped the bowel back into the peritoneal cavity. This was done in 3 animals. One hour later by gavage we gave sulfanilamide equal to a human dose of 6.5 grams to 2 dogs and to 20 grams to 1 animal (Fig. 1, slide 48). The maximum peritoneal fluid concentration was not reached until 2 to 4 hours later and then it was inadequate.

Common practice is to pour sulfanilamide, sulfathiazole, or other sulfonamide powders into the abdomen at the time of operation for perforation. In war, this is apt to be many hours after the injury. The following experiments were made to determine the best way to establish an early, high sulfonamide level in the peritoneum before peritonitis is established —preferably done at the first dressing station.

From the Surgical Service, Presbyterian Hospital and the University of Illinois College of Medicine.

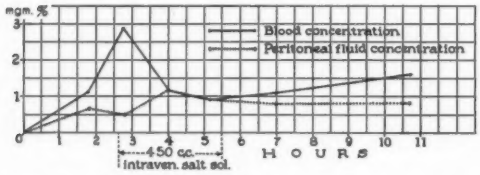


Fig. 1. Slide 48, dog, weight 16 pounds. Colon injury at 9:00 a.m. Sulfanilamide, 0.95 gram, given by gavage at 10:00 a.m. Colon injury closed at 12:20 p.m. Graph shows the concentration found after the drug was given.

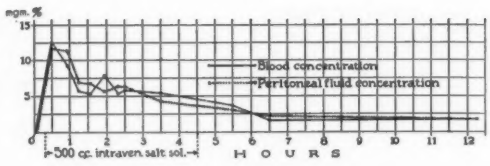


Fig. 2. Slide 61, dog, weight 20 pounds. Colon injury at 9:30 a.m. Sodium sulfathiazole, 1 gram in 10 cubic centimeters of sterile water, given by vein at 9:45 a.m. Colon injury closed at 12:00 noon.

Within 15 to 30 minutes after solutions of sodium sulfathiazole are given rapidly by vein, we found that there will be a high concentration in the exudate of an early peritonitis. This was determined by the following experiments.

A short incision was made in the midline of the dog's abdomen. The colon was identified and an incision 1 centimeter long was made transversely through all layers of the colon. We did not attempt to prevent contamination with feces. The open bowel was dropped back into the abdominal cavity, and the abdominal wall was tightly closed with interrupted through-and-through sutures. All blood for sulfonamide determination was drawn from the heart by puncture with a long needle. Peritoneal fluid was aspirated by inserting a sterile glass catheter between the stitches. An asepto syringe supplied the suction. The time of administration and withdrawal of all drugs and samples was noted. Fifteen minutes to 1 hour after the abdomen was closed a 10 per cent solution of sodium sulfathiazole, 0.5 gram per 10 pounds weight, was given intravenously, rapidly. The colon injury was closed 3 to 4 hours later.

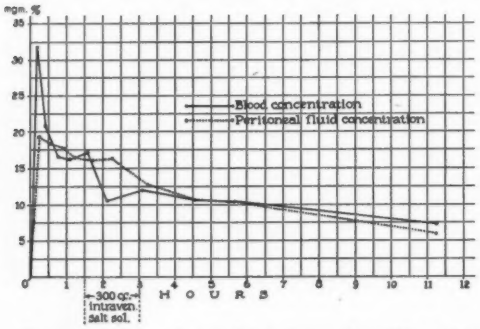


Fig. 3. Slide 59, dog, weight 28 pounds. Fifty cubic centimeters of 10 per cent turpentine emulsion was injected into the peritoneum at 9:20 a.m. Sodium sulfathiazole, 1.4 grams in 14 cubic centimeters of sterile water, was given by vein at 9:40 a.m.

In 6 animals, therapeutic concentrations in blood and peritoneal exudate were present ½ hour after administration by vein. Therapeutic concentrations were maintained for 3½ hours in spite of dilution by 500 cubic centimeters of physiological salt solution given by vein over a 4 hour period, starting ½ hour after the drug was given (Fig. 2, slide 61).

In 12 other animals, the same procedure was followed except that no fluid was given by vein. Fewer determinations were made. The same therapeutic levels were reached but they seemed to fall less rapidly.

In order to determine the effect of a strong irritant on peritoneal sulfonamide concentration, we injected 20 cubic centimeters of 25 per cent turpentine emulsion into the peritoneal cavity through a hypodermic needle in 3 dogs. No colon injury was made. Fifteen minutes after the turpentine was injected, a 10 per cent solution of sodium sulfathiazole, 0.5 gram per 10 pounds, was rapidly injected by vein. Fifteen minutes after the administration of the drug, the concentration in the peritoneal exudate was 19 to 22 milligrams per cent in each animal (Fig. 3, slide 59). These animals were given intravenous physiological salt solution.

These experiments show that during a rapid outpouring of peritoneal exudate, if the blood concentration of sulfonamide is high, the concentration in the peritoneal fluid can be raised to therapeutic levels within 15 minutes.

We have found that as the blood level fell, the peritoneal concentration lagged. The peritoneal fluid apparently acted as a reservoir

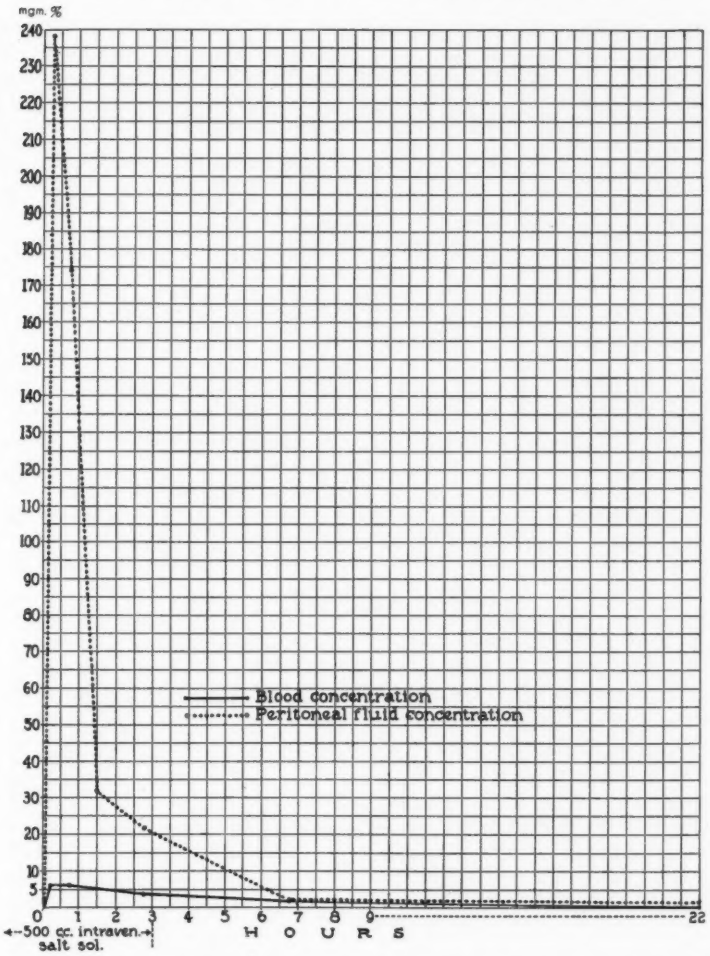


Fig. 4. Slide 41, dog, weight 17 pounds. Colon injury at 9:15 a.m. Sodium sulfathiazole crystals, 0.85 gram, placed in the abdomen when colon injury was closed at 1:45 p.m.

This corroborated the findings of Gregory, in pleural and ascitic fluids.

Similar experiments in dogs, in which the same dosage of intravenous sodium sulfadiazine were used, showed toxic injuries to the animals. This merits further study.

There is great difference of opinion as to the effect of placing various powdered or crystalline sulfonamides in the peritoneal cavity. Jackson and Coller found that there are fewer adhesions in experimental peritonitis after sulfanilamide crystals have been placed in the abdomen. Other authors have given contrary reports. Throckmorton says that in rats crystals placed intraperitoneally give an increasing cellular reaction in the following order: sulfanilamide, sulfathiazole, and sulfapyridine. They saw no severe reaction with any one. Sulfathiazole evidently took 3 to 5 days to absorb. Ryan and his co-workers say that sulfadiazine is more slowly absorbed than sulfanilamide. Ambrose and Haag found

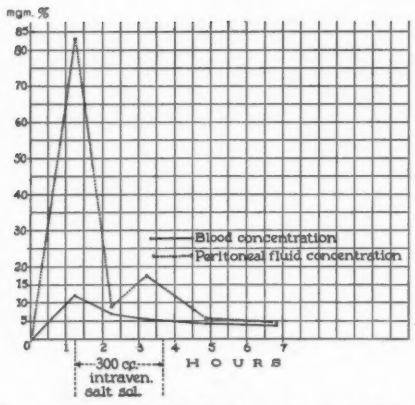


Fig. 5. Slide 55, dog, weight 18 pounds. Colon injury at 9:00 a.m. Sodium sulfathiazole, 0.8 gram in 80 cubic centimeters of sterile water, was injected into the peritoneal cavity by needle and syringe at 11:45 a.m.

that in the normal peritoneum 100 milligrams of crystals per kilogram placed intraperitoneally gave blood levels after 2 hours of: sulfanilamide, 8 milligrams per cent—this dropped after 3 hours; sulfathiazole 4 milligrams per cent—this dropped after 4 hours; and sulfapyridine, 2.5 milligrams per cent—this dropped after 7 hours. Shumacker and Haag and Spealman found similar results.

We found that soluble sulfonamide crystals placed in the abdomen in early peritonitis produces a high, immediate concentration in the peritoneal exudate. The blood concentration rapidly reaches therapeutic levels, but falls after 2 to 4 hours. This was shown in the following manner:

In 6 dogs, colon injuries were made as described previously. After 2 to 5 hours, laparotomy was performed, the injury closed, and 0.5 gram of sodium sulfathiazole crystals per 10 pounds weight was placed in the abdomen (Fig. 4, slide 41). After 15 minutes, the concentration in the heart blood was 6 milligrams per cent. The peritoneal concentration fell to 31 milligrams per cent after 2¾ hours, and at that time the blood concentration was 4 milligrams per cent. During this time, the animals received normal salt solution intravenously. In these 6 animals, the highest peritoneal concentration was 1,142 milligrams per cent, and that animal had a maximum blood concentration of 14 milligrams per cent. The blood concentration remained above 10 milligrams per cent for only 2 hours. In the 5 others, the blood concentration did not go above 10 milligrams per cent, and usually it was much below. All of these animals received intravenous salt solution immediately after closure of the injury.

In 2 other animals we used sulfanilamide crystals comparable to an 8 and 12 gram dose in an adult. The maximum blood concentration did not go above 10.6 milligrams per cent. The peritoneal concentrations of sulfanilamide were 834 milligrams per cent and 1,379 milligrams per cent after 1 hour. These dogs also received intravenous fluid after operation.

When soluble sulfonamides are placed intraperitoneally in an early peritonitis, there is a rapid elevation of blood concentration approaching therapeutic levels. This falls below 5 milligrams per cent after 2 to 4 hours. When intravenous sulfonamide has been given in the preceding 6 hours, care must be exercised to avoid summation of dosage if soluble crystals are later used intraperitoneally.

There is one other quick method of obtaining an adequate intraperitoneal concentration of one of the sulfonamides. This is the injection of suspensions or solutions through the abdominal wall or wound of entrance. It can be done with little danger. Ordinary care should prevent the injection of the fluid into a viscus. We made colon injuries in 4 dogs, and 3 hours later injected solutions of sodium sulfathiazole into the peritoneal cavity by needle and syringe. In 2 animals we injected 0.5 gram of sodium sulfathiazole per 10 pounds body weight. With both a 1 per cent and a 10 per cent solution, therapeutic concentrations were maintained in the blood for 3½ hours and in the peritoneal fluid for 4½ hours (Fig. 5, slide 55).

In 2 other animals the same procedure was carried out with 5 per cent solution of sodium sulfathiazole, 1 gram per 10 pounds body weight. This is double our usual dose. In both animals the blood concentration was 33 milligrams per cent after one hour (Fig. 6, slide 46). Therapeutic levels were maintained for 7 hours in both blood and peritoneal fluid.

If a solution of sodium sulfathiazole is injected into the peritoneal cavity before opera-

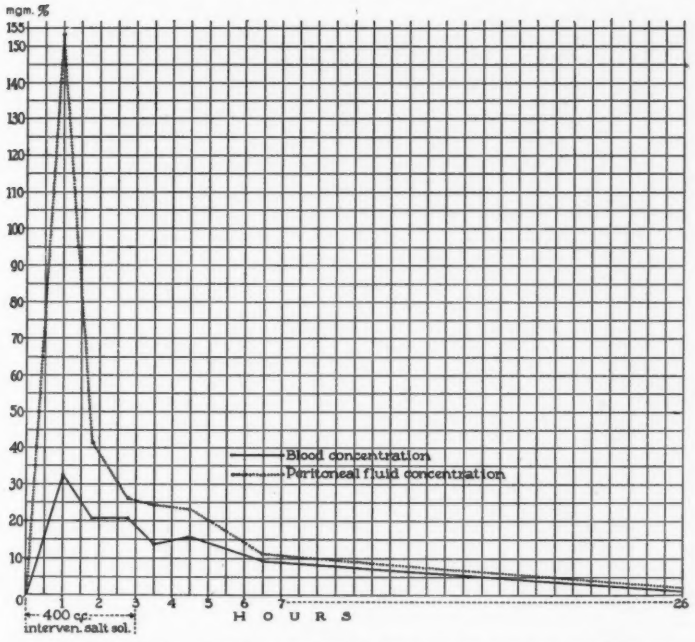


Fig. 6. Slide 46, dog, weight 15 pounds. Colon injury at 9:20 a.m. Sodium sulfathiazole, 1.5 grams in 30 cubic centimeters of sterile water, was injected into the peritoneal cavity by needle and syringe at 12 noon.

tion for traumatic peritonitis, an immediate high concentration is obtained. The blood and peritoneal fluid concentrations fall below therapeutic levels after 3 to 4 hours if the usual dose is used. If the dose is doubled, the blood concentration is high for 3 to 6 hours, and the intraperitoneal concentration maintains therapeutic levels for 7 hours.

We have shown that soluble sulfonamides placed intraperitoneally in early peritonitis result in a rapid elevation of blood and peritoneal concentration and a rapid fall in concentration after 3½ hours. We have found that the less soluble sulfathiazole crystals placed intraperitoneally produce an immediate high concentration in the exudate. This level is maintained for 24 to 48 hours. Many samples of exudate still have visible crystals at 48 hours. When the exudate was centrifuged, the concentration of sulfathiazole in the supernatant fluid remained high for at least 4 hours, but the concentrations were less than those found in the same fluids before centrifuging. We are not able to state whether the presence of undissolved crystals in the free fluid exerts any bacteriostatic effect. The blood concentration slowly rises to a peak 4 to 8 hours after administration. It usually remains below therapeutic levels.

In 5 dogs we placed 0.5 gram of sulfathiazole crystals per 10 pounds weight, intraperitoneally when closing a 2 to 4 hour colon injury (Fig. 7, slide 72). In 1 animal the blood concentration gradually rose to 10.4 milligrams per cent during 8 hours. In another it rose to 7.8 milligrams per cent in 8 hours. The 3 dogs remaining had blood concentrations of 0.9 milligram per cent to 4.7 milligrams per cent, the rise occurring in the same manner.

In another 3 dogs, a commercial preparation of finely divided crystals of sulfathiazole held in suspension was used (Fig. 8, slide 73). In 1, the suspension was injected intraperitoneally through the abdominal wall by syringe and needle 1 hour after the colon injury. In another, the suspension was injected through a

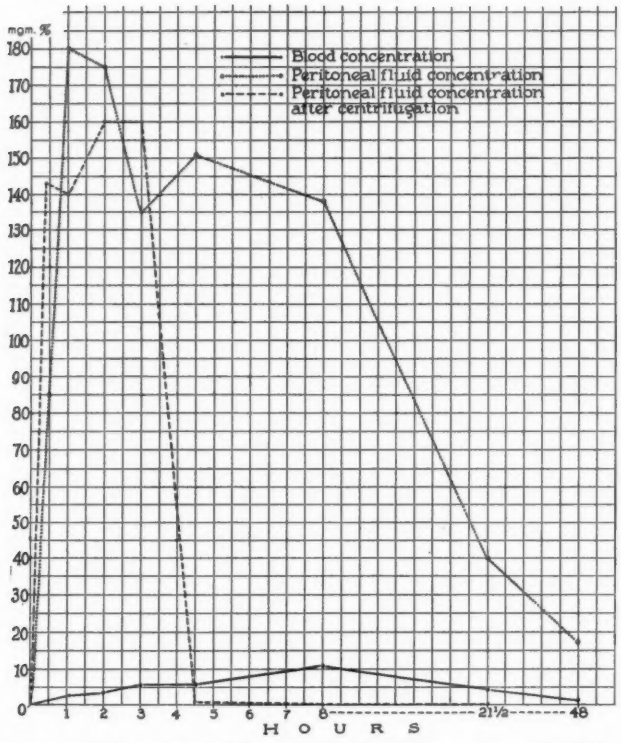


Fig. 7. Slide 72, dog, weight 10 pounds. Colon injury at 9:35 a.m. Sulfathiazole crystals, 0.5 gram, were placed in the abdomen when the injury was closed at 12:10 p.m.

catheter pushed through the wound of entrance 1 hour after colon injury. In the third, the suspension was placed in the abdomen at the time of closure of the injury. In the first 2, the colon injury was closed 2 hours after the suspension was injected. The blood concentrations rose to about 5 milligrams per cent after 2 hours, and tended to maintain this level for 6 to 8 hours. The peritoneal concentrations resembled those seen with ordinary crystals.

All animals receiving intraperitoneal sulfathiazole crystals did well, and when killed after 2 to 9 days very few adhesions were found.

As a control, the same dose of sulfathiazole crystals was inserted through a laparotomy incision without bowel injury. Examination 4 days later showed no peritoneal reaction and no fluid present. Sulfathiazole crystals were found free in the abdomen. Walter and Cole, in an abstract of an unpublished report, used sulfadiazine in the abdomen. Six to 7 days were required for complete absorption. The blood level reached a peak in 36 and 96 hours.

In another animal, a suspension of microcrystals was injected by needle without laparotomy. Five days later, examination showed no trace of peritoneal reaction. None of the injected material was found.

The use of this less soluble sulfonamide as an intraperitoneal drug will lessen the danger of summation with previously administered intravenous drug.

We have some human material in which the findings correspond to the results found in our experiments. A 20 year old male who had a 20 hour attack of acute appendicitis was operated upon and a diffuse, purulent peritonitis

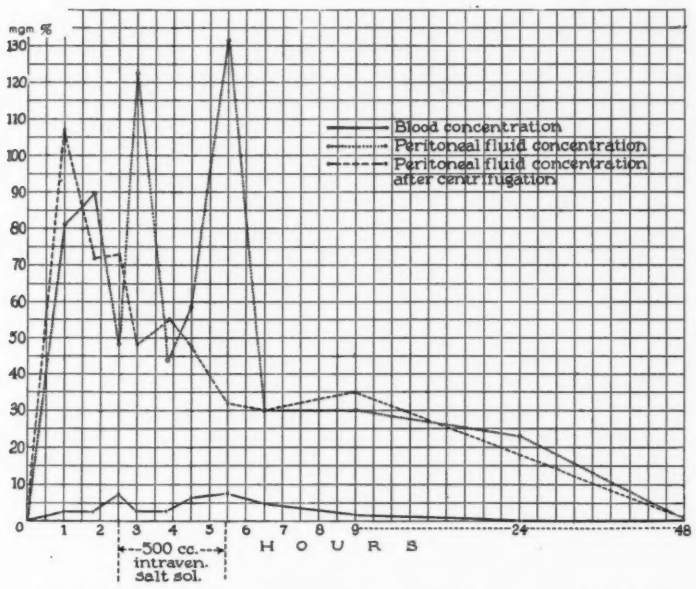


Fig. 8. Slide 73, dog, weight 16 pounds. Colon injury at 9:00 a.m. Sulfathiazole microcrystals, 0.8 gram in 20 per cent suspension, was injected into the peritoneal cavity by needle and syringe at 9:55 a.m. Colon injury was closed at 12:30 p.m.

was found. The appendix was removed and 7.5 grams of sodium sulfathiazole in 125 cubic centimeters of normal saline was placed in the peritoneal cavity just before tight closure. The blood concentration of the sodium sulfathiazole was 6.8 milligrams per cent after 30 minutes and it was 6.5 milligrams per cent after 3½ hours. Only a trace was found after 10 hours. In 4 cases in which sulfanilamide was placed in the human abdomen at operation, comparable doses being used, blood concentrations were also found to be low after 8 hours.

A man who had a colostomy developed peritonitis. Ten grams of sulfanilamide was placed in the peritoneal cavity around the colostomy. Five and one-half hours later, the blood level was 2.6 milligrams per cent. The next day he was given 5 grams of sodium sulfathiazole intravenously over a 3 hour period. One-half hour after the administration of the fluid and drug was stopped, the blood concentration was 9.5 milligrams per cent, but 12½ hours later, the blood concentration had fallen to 2.6 milligrams per cent.

A 48 year old man had a 3 day old generalized peritonitis following the giving of an enema which ruptured a diverticulitis. He was desperately ill (Fig. 9, slide 51). An abdominal paracentesis was made and 450 cubic

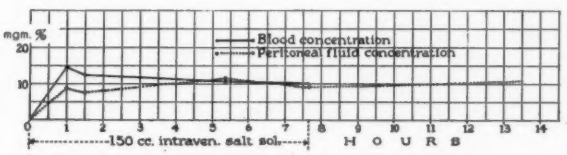


Fig. 9. Slide 51. Man, weight 150 pounds, with 72 hour old peritonitis. Sodium sulfathiazole, 7.5 grams in 150 cubic centimeters of sterile water, was given intravenously, rapidly.

centimeters of cloudy fluid was aspirated. One and one-quarter hours later, 7.5 grams of sodium sulfathiazole was given intravenously in a 5 per cent solution, rapidly. One hour later, the blood concentration was 14.6 milligrams per cent and the peritoneal fluid aspirated through the paracentesis opening had a concentration of 8.3 milligrams per cent. This patient had large amounts of intravenous fluid and plasma, but 7½ hours after the injection the blood and peritoneal concentrations were 10 milligrams per cent. He died 5 hours after this. At postmortem, the peritoneal fluid contained a sulfathiazole concentration of 10.3 milligrams per cent. In animals, we have noticed a similar flatness of the curve when death approaches.

CONCLUSIONS

Sulfanilamide given by mouth after injury to the peritoneum will not produce adequate early concentrations in blood and peritoneal exudate. A 10 per cent solution of sodium sulfathiazole may be injected intravenously without producing phlebitis. Fifteen minutes after such an injection, the effective sulfathiazole level in the peritoneum will approach that found in the blood. Therapeutic concentration in the peritoneal fluid will be maintained for 4 to 6 hours. The fall in concentration will be hastened by giving intravenous fluid if circulation is adequate. When soluble forms of drug are used, an additional dose must be administered after 8 hours if therapeutic concentrations are to be maintained.

If sodium sulfathiazole solution is injected into the abdominal cavity after the injury is made and before closure of the perforation, an immediate high concentration is obtained. The blood concentration rises to therapeutic levels rapidly and is maintained 4 to 6 hours. When sodium sulfathiazole or sulfanilamide crystals are placed in the abdomen at operation, there is a rapid high concentration of drug in the peritoneal exudate. The blood concentration rises to therapeutic levels rapidly and falls below therapeutic levels after 6 hours.

Further study may show that other soluble sulfonamides are preferable to the sodium sulfathiazole used in our studies. When relatively insoluble sulfathiazole crystals are placed in the abdomen effective concentrations are reached in the peritoneal exudate in 20 minutes. Effective concentrations of the drug are maintained in the peritoneal exudate for many hours. The concentration in the blood rises slowly and usually remains below therapeutic levels.

It is desirable to establish conditions unfavorable to bacterial growth within the abdomen as soon as practicable after injury. Such conditions should be maintained until the perforation is closed and the natural defenses of the peritoneum have dealt with the contaminating organisms.

A program for retarding the development of peritonitis after bowel perforation is suggested:

1. One-half gram of sodium sulfathiazole per 10 pounds body weight should be injected intravenously as a 5 or 10 per cent solution. This injection should take from 2 to 4 minutes and should be a first-aid measure. Intravenous fluid, plasma, or blood should follow. As an alternate procedure, a soluble drug or a suspension of sulfathiazole microcrystals may be injected directly through the abdominal wall, or in some cases through the entry wound.

2. As soon as possible, laparotomy should be performed. At that time, a relatively insoluble sulfonamide, such as sulfathiazole, should be placed in the abdomen. When soluble sulfonamides are used in the abdomen, additional drug must be administered after 8 hours. When slowly soluble sulfathiazole is used in the abdomen, additional drugs need not be administered for 24 hours.

REFERENCES

1. Ambrose, A. A., and Haag, H. B. Surgery, 1942, 12: 206.
2. Gregory, R. Arch. Int. M., 1942, 69: 429.
3. Haag, H. R., Spealman, C. R., and McCue, H. M. Surgery, 1941, 10: 572.
4. Jackson, H. C., and Coller, F. C. J. Am. M. Ass., 1942, 118: 194.
5. Long, Perrin H. J. Am. M. Ass., 1943, 121: 303.
6. Lyons, C., and Burbank, C. Surg. Gyn. Obst., 1942, 74: 571.
7. Ryan, J. D., Bauman, E., and Mulholland, J. J. Am. M. Ass., 1942, 119: 484.
8. Saduck, J. F., Black, F. G., and Seymour, A. Yale J. Biol., 1940, 12: 681.
9. Shumacker, H. B. Surgery, 1942, 12: 81.
10. Taylor, Gordon. Surg. Gyn. Obst., 1942, 74: 375.
11. Throckmorton, T. D. Surgery, 1942, 12: 907.
12. Walter, Leroy E., and Cole, Warren H. Bull. Am. Coll. Surgeons, 1943, 28: 50.

THE DISTRIBUTION OF NERVES IN THE ADULT HUMAN MYOMETRIUM

EDWIN F. HIRSCH, M.D., and MARY E. MARTIN, M.D., Chicago, Illinois

ACCORDING to recent summaries (3, 12) no detailed descriptions of the anatomical relations of the intrinsic nerves to the muscle and vascular structures of the uterus have been published. The information compiled in these summaries is general and to some extent confused. A study of large nerve trunks and branches in the adult human endometrium was reported recently by State and Hirsch. They observed large nerve trunks and smaller branches in the basal portion of the endometrium and traced the terminal branches of the nerve fibers to blood vessels near the endometriomyometrial junction. Some fibers seemed to end freely in the stroma of the endometrium. Large nerve trunks in the myometrium, according to their observations, contained many nonmyelinated and some myelinated fibers. The nonmyelinated fibers, accordingly, agreed in structure with vasomotor nerves elsewhere in the body, are postganglionic, and probably belong to the sympathetic nervous system. The myelinated fibers had the anatomical structure of sensory nerves. According to Albert Kuntz, an abundance of nerve fibers has been observed in the uterine muscle and along the blood vessels. No one, however, has traced the course of these fibers in the myometrium for the purpose of establishing details of distribution and anatomical connections. These details have significance because physiologically, according to Kuntz, the sympathetic nerves supplying the uterus exert a motor influence; the parasympathetic nerves an inhibitory effect. Also, the sympathetic supply includes the vasoconstrictor, and the parasympathetic supply the vasodilator fibers for the female genitalia.

From the review by Daron and his study of the endometrium in Macacus rhesus, the following general statements of the arterial circulation in the uterus are obtained. Branches from each laterally placed uterine artery pass inward and upward and encircle the wall of the uterus. They penetrate the inner portions of the myometrium and continue into radial divisions that supply the coiled or spiral arteries which extend as true terminal vessels into the outer portions of the endometrium. Smaller arteries of a second type supply the basal zone of the endometrium. Daron stated that the flow of blood through the spiral arteries is controlled by: (1) tortuosity, and (2) contraction of the radial arteries in the inner fourth of the myometrium. These constrictions, according to Daron, produce at the onset of menstruation an ischemic necrosis of the superficial part of the endometrial mucosa. The mechanism responsible for this constriction of the radial arteries is not clear, except on the general basis of hormonal action. Daron stated that the basal arteries are not involved in these cyclic changes.

Jones and Brewer reconstructed from serial sections a model of a radial artery and the endometrial distribution of its spiral artery branches in the human uterus. They also described a constriction of the spiral vessels in the myometrium near the endometrial edge. These authors and others believed that constriction of the spiral arteries is important in the functional activities of the uterus and is accomplished through some hormonal action. Brewer observed an association between rhythmic changes in the fragility of the capillaries of the skin and the menstrual cycle. He concluded that the increased ease with which capillary hemorrhages are produced in the skin just before and at the onset of menstruation is due probably to a vascular spasm. This association of systemic vascular activity with menstrual periods indicates a generalized instead of a localized (uterine) vascular phenomenon.

From the Henry Baird Favill Laboratory of St. Luke's Hospital and the Department of Pathology of the University of Chicago.

Aided by the Winfield Peck Memorial Fund.
Dr. Martin, The John Jay Borland Fellow.

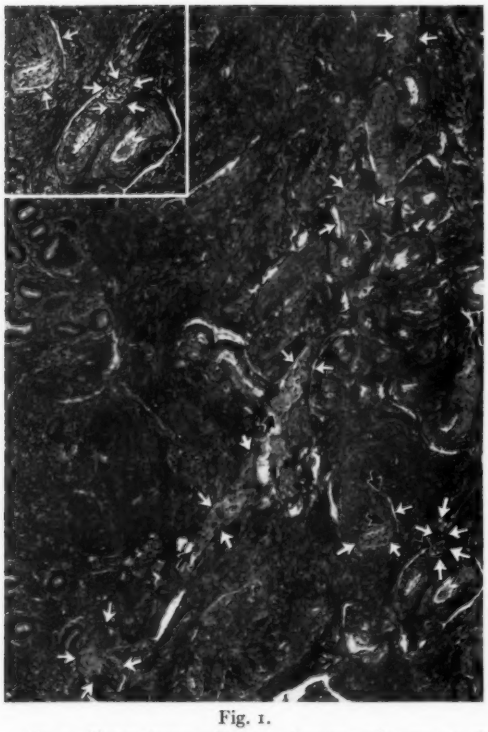


Fig. 1.

Fig. 1. Photomicrograph illustrating several segments of a large nerve trunk extending diagonally through the inner portion of the myometrium, associated with a group of radial and spiral arteries and entering the basal portion of the endometrium. A smaller nerve trunk is below on the right near another radial artery. (Enlargement of a low power photomicrograph.) Insert in upper left corner. ×72. Section from opposite lower corner of photomicrograph, containing a nerve trunk in the myometrium and two transverse sections of spiral (or radial) arteries associated with another nerve trunk. Below the latter nerve trunk and in the angle between the two arteries is a sensory corpuscle.

Fig. 2.

Fig. 2. Photomicrograph illustrating a small nerve trunk, *A*, passing through the myometrium and approaching a radial artery, *B*. Trunks like this traverse the deeper portions of the myometrium in a similar manner. At the base of the endometrium is a small nerve trunk. (Enlarged from a low power photomicrograph.)

An investigation of neurovascular relations in the uterus, therefore, has merit because of the known physiological vasomotor action of these nerves and its implications in uterine function; and also, if such anatomical relations are found, the concepts of vasomotor control which are accepted for other tissues of the body may be applied in the understanding of uterine physiology.

MATERIAL AND METHODS

The distribution of the nerves in the adult myometrium was studied in sections cut serially and stained according to Goldner's modification of Masson's trichrome staining method. Mature nulliparous uteri were used, the one obtained postmortem from the body of a woman aged 19 years, the other removed surgically from a woman aged 36 years. They had no unusual changes. Each uterus was opened by crucial incisions of the anterior wall and was fixed in Bouin's solution[1] at icebox temperature for 3 days. Then the uterus was cut longitudinally into four pieces and fixed for 3 more days.

Blocks measuring 1 by 0.8 by 0.8 centimeter for embedding were cut from the lateral, anterolateral, and posterolateral walls begin-

[1]Satured aqueous solution of trinitrophenol, 70 c.c.; solution of formaldehyde, 25 c.c.; and glacial acetic acid, 5.0 c.c.

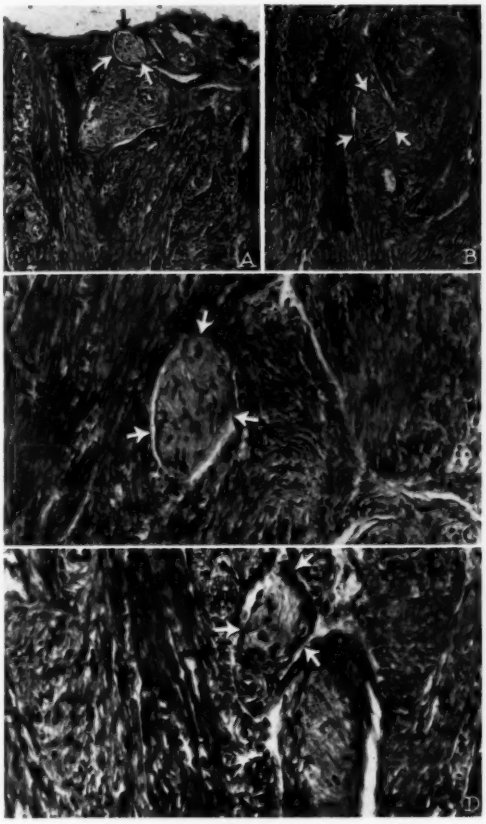


Fig. 3.

Fig. 3. Photomicrographs illustrating nerve trunks in the myometrium of the uterus. A, ×85, a large nerve trunk associated with blood vessels; B, ×85, and C, ×145, nerve trunks in the muscle tissues; and D, ×180, a small trunk near a blood vessel.

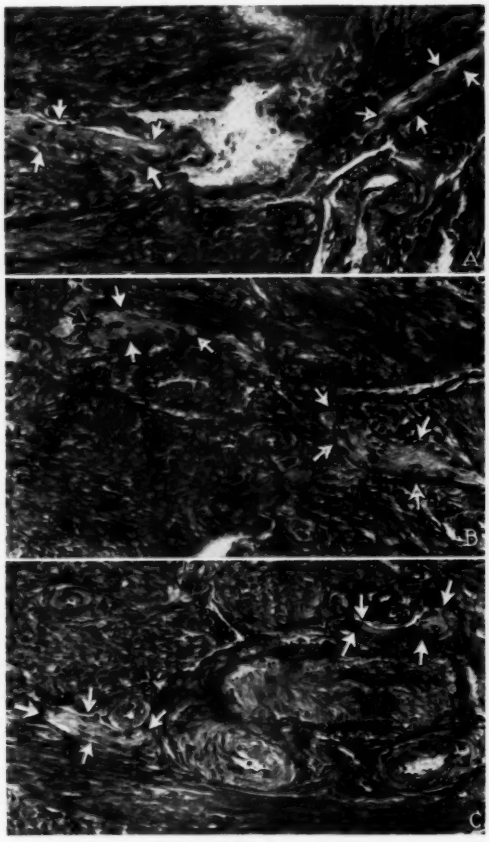


Fig. 4.

Fig. 4. Photomicrographs illustrating small nerve trunks which in the inner fourth of the myometrium made serial contacts with radial or spiral arteries. A, ×187, two segments of a trunk near a venous channel; B, ×155, two segments of a trunk in the muscle tissues; and C, ×155, two segments of a trunk representing its approach to and egress from a radial artery.

ning at the level of the internal os. These blocks were fixed for an additional 48 hours in Bouin's solution, embedded in celloidin and paraffin according to the method of Bensley and Bensley and sectioned serially at 8 microns thickness. With Goldner's modification of Masson's trichrome stain the axis cylinders of the nerve fibers are pale red; the neurilemma sheaths, pale green; the perineurium and endoneurium, purple-red; the fibrillar connective tissues, bright green; and the smooth muscle, brick-red.

OBSERVATIONS

Large nerve trunks extend upward and inward in the lateral wall of the body of the uterus and divide into smaller trunks which penetrate the inner portions of the myometrium. The large trunks lie in the periarterial fibrous tissues (Fig. 3, a) for certain portions of their distribution, but at other levels (Fig. 3, b, c, d) they pass directly through the muscle tissues of the myometrium. The smaller trunks in the outer portions of the myometrium also extend through the muscle and

Fig. 5a.

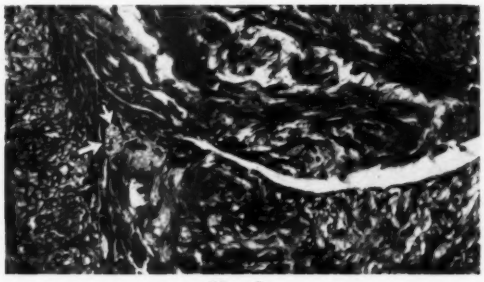


Fig. 5b.

Fig. 5. Photomicrographs, ×187, illustrating nerve trunk relations with radial or spiral arteries. A, Two separate nerve trunks near one of these vessels; B, a small nerve in the adventitia of an artery; C, a small nerve near an artery and in the adventitia, a sensory corpuscle.

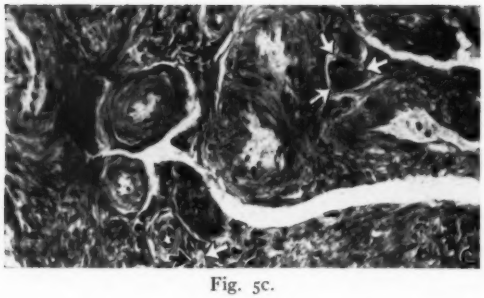


Fig. 5c.

make contacts with arterial branches (Fig. 2). In this way, single nerve trunks establish vascular connections with many arterial branches. This manner of distribution is noted especially in the inner fourth of the myometrium where the nerve trunks connect with several or a series of radial arteries (Fig. 4, c; Fig. 5, a). Between the vascular contacts, the nerve trunks extend through the muscle with little associated stroma (Fig. 4, b) or are embedded in the fibrous connective tissues between muscle bundles and in tissue crevices about venous channels (Fig. 4, a). Small twigs (Fig. 5, b and c) are given off at various levels. Some large nerve trunks after connections with blood vessels (Fig. 1) pass through crevices at the endometriomyometrial junction and are distributed to the endometrium.

The nerve trunks in the inner fourth of the myometrium pass vertically for considerable extents. They make contacts with the radial arteries before these vessels divide into the

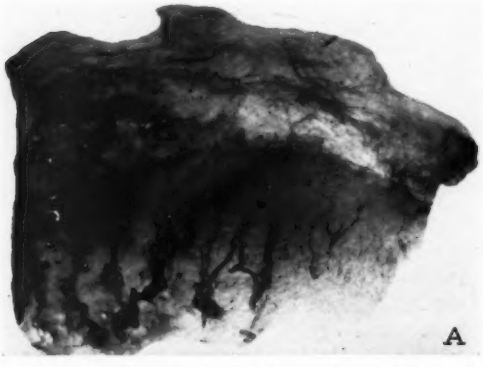


Fig. 6. A, Photograph of a cleared segment from the inner fourth of the myometrium and endometrium of a uterus whose uterine arteries had been injected with a 5 per cent solution of vinylite dissolved in acetone and containing rotaline blue B. The photograph illustrates the branchings of radial arteries into spiral arteries. At this level nerve trunks extend from one system of vessels to another in series. B, Photomicrograph, ×187, illustrating a structure considered to be a sensory corpuscle in a crevice of the myometrium.

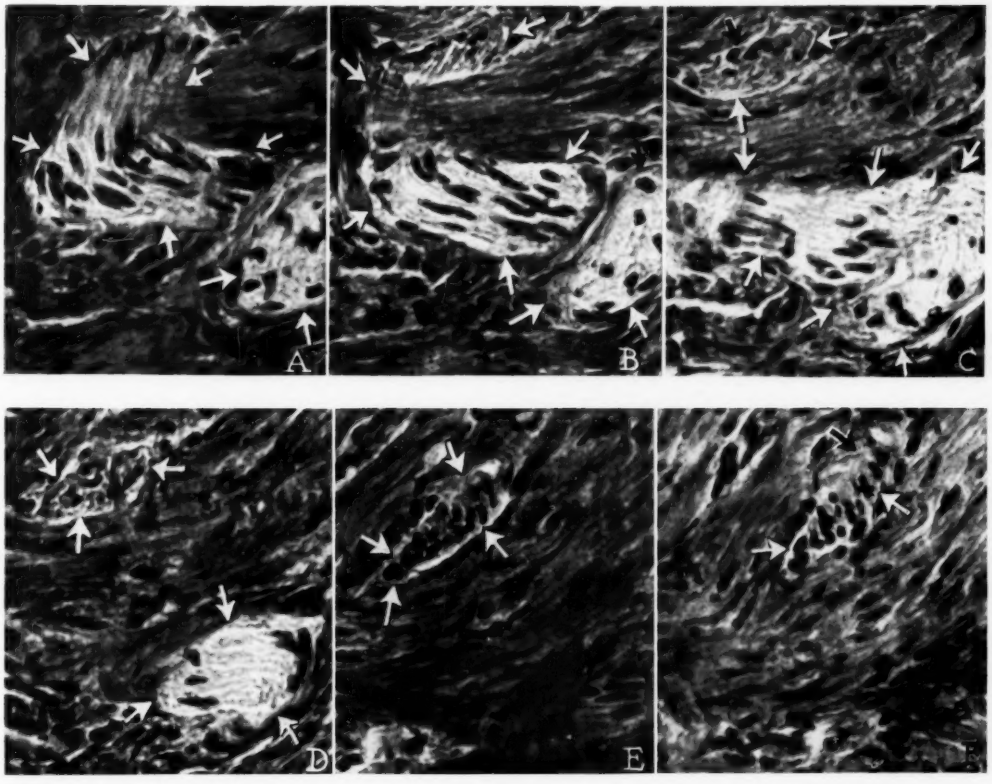


Fig. 7. Photomicrographs, ×340, illustrating a corpuscular sensory organ and its nerve trunk connection in consecutive serial sections. The series is unbroken to E. One section between E and F was not photographed, to avoid duplication, and one after F had only a small oval mass of fibrillar tissue, at the tip of the corpuscle. At A, fibers are streaming up to the corpuscle from a nerve trunk; at B, only a few fibers remain; C and D, include the corpuscle and also the nerve trunk. E and F, illustrate the more distal portions of the corpuscle.

spiral branches to the endometrium and some also connect with the basal arteries. They follow the same general pattern of distribution, making contacts with a series of blood vessels and between the vessels passing through the myometrium. A single nerve trunk was traced through its contacts with five radial arteries. The association of nerve trunks with radial arteries was investigated also by tracing spiral arteries in serial sections from the endometrium into the myometrium. A nerve trunk or branch was demonstrated with many of these vessels. Those without may have had small nerves that escaped observation.

The search for nerve ganglia along the nerve trunks in the body of the uterus was futile. At some levels the nuclear content of the nerve trunks appeared to be greater than at other levels, but no significance was attached to this variation in structure. Small nutrient arteries were present at various levels in large nerve trunks. The actual endings of the nerves in the walls of blood vessels and in the myometrium, except as mentioned later, were not demonstrated by the staining methods used in this study. Emphasis in the project was on the general distribution of the nerves and their anatomical relations to the blood vessels and muscle tissues of the uterus, for which the trichrome stain was adapted.

The presence of myelinated fibers in nerve trunks of the uterus has been recognized by

Dahl, Mabuchi, and others. These fibers have the anatomical structure of sensory nerves, and like sensory nerves in other tissues of the body, should have sensory nerve endings. Nerves to the large blood vessels of the extremities, according to L. Hirsch contain both myelinated and nonmyelinated fibers. He found that the afferent fibers always were myelinated and that the endings in the walls were: (1) branchings and coils of individual nerves without capsule, and (2) typical lamellar corpuscles. The corpuscles varied in size and form, and consisted of a peripheral layer of concentrically arranged spindle cells. In the center, in addition to the nerve coils, were plump, darkly stained, oval nuclei. These receptor organs resembled the Vater-Pacinian corpuscles, the Krause nodes, and intermediary forms. Their maximum diameters ranged from 0.08 millimeter to more than 1 millimeter. Dahl did not find nerve endings in the uterus. Keiffer, however, described corpuscles of the Vater-Pacinian varieties in the cervix, and others in the myometrium.

In our study of the distribution of nerves in the myometrium, small ovoid structures were found to extend a short distance from the margins of nerve trunks into the muscle tissues (Fig. 6, b) and into the adventitial coats of medium sized arteries (Fig. 5, c). One of them lying in a crevice in the muscle (Fig. 7) was traced directly to a nerve trunk. Others, after their tissue structure had been recognized, were not so clearly identified with nerves. The encapsulated corpuscles found were about 80 to 90 microns long, 30 to 35 microns wide, and 15 to 18 microns thick. A cluster of small, darkly stained, compact oval nuclei was in the center of the corpuscles and a small amount of fibrillar stroma was along the margins and at the tip.

SUMMARY AND CONCLUSIONS

Large nerve trunks enter the body of the uterus from below and laterally. They extend along the branches of the uterine artery, then pass through the myometrium to join with other arterial branches, and divide into smaller trunks that are distributed in a similar pattern. In the inner portion of the myometrium, nerve trunks extend through the muscle and connect with a series of radial arteries. Many small branches whose ultimate endings were not determined are given off by the nerve trunks to blood vessels and muscle tissues. The presence of the small branches suggests an even more extensive vascular and muscle tissue distribution than actually was demonstrated by this study. Large nerve trunks also extend into the endometrium. The nerve trunks contain nonmyelinated or vasomotor and myelinated or sensory fibers. In the search for sensory end organs, corpuscles of the Vater-Pacinian variety were found in crevices of the muscle tissues and, more often, in the adventitia of branches of the uterine artery. They were oval structures about 90 microns long, 35 microns wide, and 18 microns thick. The center had a cluster of compact oval nuclei and the periphery was a small amount of fibrillar stroma.

The abundance of nerves in the body of the uterus and the connections they make with branches of the uterine artery, especially in the inner fourth of the myometrium where they connect with series of radial arteries, seems to provide a nervous tissue medium for effecting a control of the vascular phenomena which are associated with uterine physiology.

REFERENCES

1. Bensley, R. R., and Bensley, S. H. A Handbook of Histological and Cytological Technique. P. 56. Chicago: University of Chicago Press, 1938.
2. Brewer, J. I. Am. J. Obst., 1938, 36: 597–610.
3. Brown, W. H., and Hirsch, Edwin F. Am. J. Path., 1941, 17: 731–739.
4. Dahl, W. Ztschr. Geburtsh. Gyn., 1916, 78: 539–601.
5. Daron, G. H. Am. J. Anat., 1936, 58: 349–419.
6. Goldner, J. Am. J. Path., 1938, 14: 237–243.
7. Hirsch, L. Arch. klin. Chir., 1926, 139: 225–239.
8. Jones, H. O., and Brewer, J. I. Am. J. Obst., 1939, 38: 839–859.
9. Keiffer, M. H. Bull. Acad. Belgique, 1934, 14: 186–210; 1936, 16: 508–520.
10. Kuntz, Albert. The Autonomic Nervous System. Pp. 308, 310. Philadelphia: Lea & Febiger, 1929.
11. Mabuchi, Kozaburo. Mitt. Med. Fak. Univ. Tokyo, 1924, 31: 385–495.
12. State, D., and Hirsch, Edwin F. Arch. Path., Chic., 1941, 32: 939–950.

ANTERIOR SACRAL MENINGOCELE

FREDERICK A. COLLER, M.D., F.A.C.S., and RICHARD G. JACKSON, M.D.,
Ann Arbor, Michigan

ANTERIOR sacral meningocele is a rare condition which is of importance only because of the symptoms it may produce and because if unsuspected, misdirected treatment may lead to meningitis. Review of the literature reveals a total of 23 cases, including ours. Eighteen of these were treated, with a mortality of 44 per cent. Eight were cured and 2 remained the same. A proper note of caution in the treatment of meningoceles was early sounded by Tulp when, in 1652, after an unhappy experience with a posterior meningocele, he said, "Beware, Oh surgeons, lest you open anything improperly which may easily kill a person."

In 1837, a distinguished surgeon, whose name at his own request was omitted (1), reported a case discovered at autopsy in a patient who had died 4 days following delivery in which was found a large cyst filling the hollow of the sacrum that prevented normal delivery. This case was mentioned in 1858 by Buhl (2), credit being given to Bryant who presided over the meeting of the London Medical Society before which the case was presented. In 1871, Emmet described a case in which he aspirated 3 inches beyond the anus a tumor which he took to be a kidney cyst and the patient died of "uremia." Autopsy revealed that half of the three lower sacral vertebrae were deficient on the right side, and the pedicle of a cyst that filled the pelvis passed through a funnel-shaped opening into the spinal canal in this area. He suggested that the septum between the 2d and 3d sacral foramina on the right had not formed, thus leaving a defect through which the sac herniated and that the larger defect was due to absorption of bone because of pressure by the sac. Coqui, describing Hofmokl's case (1878) stated that the tumor reached up to the iliac fossa, that "part of the sacral bone was lacking, and an intervertebrale foramen enlarged." The treatment was not discussed. Hugenberger, in 1879, described a case of a woman with pregnancy, delivery, and death from "peritonitis." The ruptured meningocele containing cauda equina was found at autopsy. Lohlein (1895) reported a case complicating pregnancy in which he aspirated the tumor three times, opened it through the vagina, and later opened it through the rectum with subsequent healing. Cerebrospinal fluid was obtained on the first two punctures, pus thereafter. As the patient did not develop meningitis, closure of the pedicle must have occurred. Kroner-Marchand (1881) aspirated, then opened an anterior sacral meningocele through a vaginal incision with resultant meningitis and death. Thomas (1885) relates the history of a patient, a woman of 28 years, who presented a cyst filling the hollow of the sacrum lying posterior to the rectum. The lesion was untreated and its character can only be surmised. He reports in detail the case history of a girl of 19 who was found to have a cyst attached to the hollow of the sacrum that pushed the uterus and rectum forward and to a very great extent "occluded the vaginal canal." The cyst was first typed with production of fever for several days. Some months later she was operated upon through the vagina, the sac opened and within 24 hours its walls sutured to the vaginal mucosa. The patient died of infection and with symptoms suggestive of "tetanus," probably meningitis. The first report of treatment of the condition through a dorsal incision was in 1903 when Pupovac performed the operation, resecting part of the wall of the meningocele and closing the remainder by suturing it together, with resultant cure. In the same year Robinson, operating upon an 11 months old infant, ligated the pedicle of a similar tumor with silk. The child died with meningitis 10 days later and autopsy revealed a defect in the right side of the 12th thoracic and all of the lumbar vertebrae with protrusion of the sac in this area. The pedicles of the transverse processes of these vertebrae were absent and the vertebral bodies were irregular and fused. Willard's case (1904) was untreated and the subsequent course not known. Nieberding (1904) visualized the meningocele by laparotomy but did not touch it. After aspiration later, further treatment was refused. Neugebauer (1905) reported aspiration of such a tumor in a patient who refused radical treatment. He states that the patient died 3 weeks later by accident. Grossman (1906) successfully treated a patient by exposing the tumor through a posterior incision, cutting the pedicle and sewing

From the Department of Surgery, University of Michigan Hospital, Ann Arbor, Michigan.

Aided by The James and Elizabeth Inglis Fund for Surgical Research.

Fig. 1. Anteroposterior view of the pelvis showing appearance of the sacrum.

it to the periosteum of the sacrum. In this 6 months old baby the tumor presented itself in the right gluteal region. Its pedicle passed through the greater sciatic foramen into a defect in the three lower sacral bodies on the right side. Coqui (1916) summarized the literature up to that time and reported a case of his own in which, at laparotomy, he cut the pedicle and tamponaded it with gauze. A fistula formed which drained spinal fluid for 6 months, then healed, and the patient had no further trouble. He emphasized caution in treating these tumors, feeling that they should be left alone if they caused no symptoms. He stated that it might be better to do a cesarean section and sterilization when pregnancy occurred, leaving the tumor alone. Roux (1918) described the case of an 8 year old boy who complained of constipation since birth, with frequency and incontinence of urine. After aspirating the tumor twice through the left hip region, he attempted injection with a solution of iodine, potassium iodide, and glycerine. The child developed violent pain after 2 cubic centimeters had been injected and, although 160 cubic centimeters of fluid were aspirated, he had violent headaches for 2 days. Through a lower abdominal incision the neck of the tumor was then cut and sutured with catgut, and a good recovery was made. Weber (1921) reported the case of a woman 29 years old with a double vagina and double uterus with a cystic tumor filling the pelvis. This was removed by laparotomy. The pedicle of the tumor lying in the medium line at the inferior part of the sacrum was ligated. Meningitis supervened, but the patient recovered. Kennedy (1926) reported excision of a rectal polyp apparently arising from the coccyx in a child of 22 months. Clear fluid flowed from the pedicle. The child died of meningitis and at autopsy the pedicle was found to be continuous with a meningocele which passed into a large opening in the anterior surface of the sacrum. Sabatini (1927) removed a posterior meningocele in a child of 3 months. Vomiting and distention developed. Rectal examination revealed a large retrovesical tumor with a pedicle leading to the sacrum, but because of the poor condition of the patient, nothing was done and the child died 2 days later. At autopsy, the anterior meningocele was found to contain nerve tissue, cystic spaces lined with cylindric epithelium, and stratified squamous epithelium with all layers of the dermis, but no sebaceous or sudoriferous glands or cornification. He concluded that teratomatous formation existed. Demel (1928) also described a meningocele which presented over the sacrum with a pedicle that passed through the foramen suprapiriforme. The pedicle was closed by suture ligature and plastic use of the surrounding soft parts. Postoperative x-ray film showed an anterior sacral cleft two fingerbreadths wide at the level of 1st sacral, becoming twice as wide toward the lower segments. Follow-up after 2 years showed no recurrence. He states that the operative treatment is justified only when conditions such as desire for pregnancy or complications resulting from displacement of surrounding organs are present. Drennan (1929), using the posterior approach, opened a meningocele in a patient whose complaints had been increase in the length of the menstrual periods with passage of clots and pain, and after removing the fluid, closed the wound loosely, not ligating the pedicle of the sac. Death resulted from meningitis. At autopsy, the anterior part of the sacrum from the 3d sacral vertebra down was absent, the sac protruding in this area. Posteriorly, the laminae of the sacral vertebrae and the coccyx were present. Pick (1929) treated a 32 year old soldier who complained of lifelong constipation with obstipation for 5 days and acute lumbar pain and headache; he had a temperature of 102 degrees, white blood cell count of 6400, and a palpable retrorectal tumor, by aspiration of the tumor through the rectum. Meningitis and death resulted, and at autopsy the coccyx and "some sacral vertebrae" were missing. The connection between the sac and the spinal canal was assumed but not demonstrated. Luth (1937), while doing an appendectomy in a 15 year old girl, palpated a cyst

the size of a child's head in the pelvis. It was retroperitoneal and displaced the uterus and adnexa forward. When he attempted to enucleate it, it ruptured discharging a serous, clear fluid, and the cavity was found to connect with a wide fissure of the sacrum. Part of the wall of the cyst was resected and tamponage with iodoform gauze was carried out. Postoperative x-ray examination of the spine revealed absence of the spinous process of the last 2 thoracic vertebrae, asymmetry of the sacrum with a widely open hiatus sacralis. Death from meningitis occurred, and autopsy revealed an anterior sacral meningocele extending toward the right side of the pelvis. The author concluded that treatment of this condition should be conservative, and that, if symptoms made operation necessary, the posterior approach was best, with resection of part of the sacrum if necessary, as laparotomy constituted a greater risk on account of the large vessels. Santy (1938), using the posterior approach, dissected out the wall of an anterior meningocele, finding and removing two small dermoid cysts also. After operation the patient had headaches and temperature elevation to 104 degrees, with drainage of clear fluid from the wound. The temperature became normal in 1 month, but a fistula draining clear fluid persisted for 6 months. This patient's complaints before operation had been constipation and pain in the left hypochondrium radiating down the left leg. Examination had revealed a small swelling in the perineum and a retrorectal tumor. Neurological examination showed hypotonic but equal patellar reflexes and absence of the right Achilles reflex but no muscle weakness. X-ray examination showed loss of substance corresponding to the usual situation of the lower opening of the sacral canal, with deformity and deviation to the left of the last sacral vertebra. Microscopic section of the sac wall showed nerve cells and fibers, and areflexia and hyperesthesia of the lower extremities was noticed after operation, with gradual return of function.

Our patient, N. H. (488890), a 22 year old single, white, female student was first seen in June, 1941, complaining of constipation. She stated that she had been constipated "all her life," and in the last 2 years had required daily enemas. She had had no bloody or tarry stools, no tenesmus or weight loss.

The past history was noncontributory except that the patient stated that she had always preferred to sit on one buttock or the other, having a vague sense of discomfort if she sat squarely. The family history was that one brother had died at the age of 22 months of "bowel obstruction," and a sister had died at the age of 10 months of spinal meningitis.

Physical examination was negative except for rectal examination, when a firm, slightly fluctuant, grapefruit-size, nontender, slightly movable tumor was felt in the pelvis. No mass was palpable on abdominal examination. Neurological examination was negative. Review of the x-ray films showed profound deformity of the sacrum, suggesting nondevelopment of the right half, displacement of the left half toward the left, and displacement of the coccyx to the horizontal position. The rectum was displaced and compressed, and the sigmoid was displaced upward as was the small bowel. The left innominate bone was rotated somewhat and the sacroiliac joints slightly widened. The bone margins were smooth and not eroded. It was our opinion that the patient had a developmental lesion which might be a dermoid or an anterior sacral meningocele, and to gain perspective it was decided to follow her course for 2 months and repeat the barium enema and examination at that time to see if the tumor was growing.

Fig. 2. Barium enema showing compression of the rectum by the tumor.

The patient returned September 12, and the tumor showed no increase in size by physical examination. Because of continued constipation and the possibility of future interference with child bearing, she was advised to have the tumor removed.

At operation an incision was made through the lower right midrectus muscle thus exposing a retroperitoneal tumor, gray in color and fluctuant, which pushed the ureters and pelvic organs forward. It was clear that the tumor could not be adequately exposed by this anterior approach. Accordingly, the abdomen was closed and the patient turned on her face in the jackknife position. A vertical incision, just to the right of the midline over the coccyx was made and carried down to bone. The tip of the coccyx was removed, the tumor wall exposed, and clear fluid was

Fig. 3. Postoperative roentgenogram showing the position of the pedicle as marked by the silver clips.

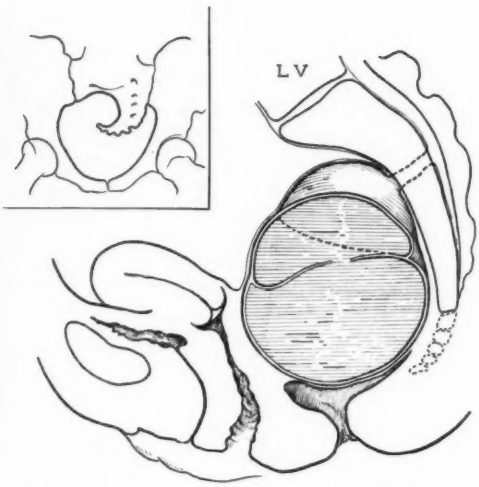


Fig. 4. Diagram to show configuration of the tumor. The dome of the tumor was at a higher level than shown here.

aspirated. When the meningocele was opened, 500 cubic centimeters of clear fluid was aspirated revealing a grapefruit size cavity, which in turn opened at its apex into a second smaller cavity which in turn opened into a third and smaller sac from which a pedicle passed into the spinal canal through an anterior sacral hiatus. No nerves were seen in the pedicle or sac. The pedicle was suture ligated with No. 1 black silk. On bilateral jugular compression, spinal fluid issued from the pedicle above the ligature. This opening was closed with two silver clips. A small metaphen-in-oil pack was then placed about the pedicle to create adhesions and the end of the pack was brought out through the wound. A portion of the sac was excised for microscopic examination and the wound was closed in layers with interrupted sutures of fine black silk. The patient was transferred to bed in the prone jackknife position, supported on pillows. The pathologist's report on the sac wall was: "Dense fibrous connective tissue."

After operation the patient was kept in the prone jackknife position with her hips higher than her head for 3 days. She was then allowed to turn on her side occasionally, her hips being kept elevated, and after the 6th day, was allowed to turn on her back to aid drainage from the wound and to allow the pelvic organs to fall back into place and obliterate the sac. The foot of the bed was lowered on the 13th day. Immediately after the operation, the patient was started on a liquid diet without fruit juices, and was given paregoric, 4 cubic centimeters four times a day, to prevent bowel movements and contamination of the posterior wound. She had no bowel movements until paregoric was stopped and a general diet started on the 13th day, and thereafter had regular bowel movements.

Her temperature rose to 100 degrees the first day, 101.6 the second day, and thereafter ranged between 99 and 101.4 degrees until the 18th day when it fell to normal and remained normal. On the 3d day, examination showed temperature of 100.6 degrees, white blood cells of 12,000. Although there were no signs of meningeal irritation, a lumbar puncture was done and spinal fluid, which was grossly clear, was allowed to drain through the needle until flow ceased, 30 cubic centimeters being removed to relieve pressure on the ligated pedicle. Examination of the fluid showed 28 cells per cubic millimeter, and culture showed no growth. Sulfathiazole was started as prophylaxis against the development of meningitis, 2 grams being given initially, and 1 gram every 4 hours thereafter until the 8th day, when the dose was reduced to 4 grams per day. The white blood count on the 11th day was 9,600.

The anterior wound healed well. The posterior wound was kept walled off with oiled silk, the dressing being changed first on the 6th day. There was a small amount of sanguinopurulent drainage about the pack at this time but the wound seemed to be healing well. The sutures were removed on the 8th day and on that day profuse watery,

yellow drainage from the wound began. The pack was removed on the 10th day, and the drainage continued in gradually decreasing amounts. The patient was allowed up out of bed on the 14th day and went home on the 20th day. At this time there was a small amount of drainage from the wound daily. A 6 inch by 3 inch area of anesthesia on the posterior aspect of the left midthigh extending around to the anterolateral aspect was noted on the 10th day and was present when the patient went home. The patient was seen at weekly intervals, and 3 weeks after she left the hospital the posterior wound was healed, the area of anesthesia was smaller, and there were no reflex or motor changes on neurological examination. She felt well and was ready to start back to school. Checkup examination on March 20, 1942 showed her to be in perfect general condition and the rectal examination disclosed only a vague sense of thickening behind the rectum.

OBSERVATIONS

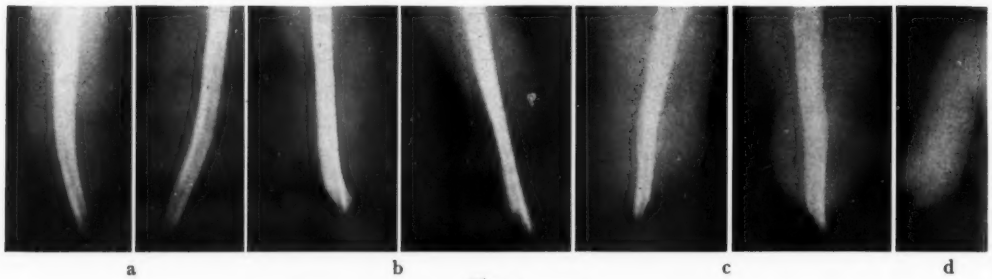
Anterior sacral meningocele usually manifests itself within the first 3 decades of life. It occurs more frequently in females than in males, the ratio being 20:3 in the reported cases. The youngest patient was 3 months old, the oldest 36 years old. The meningocele enters the pelvis through an anterior sacral defect which is usually laterally placed and occurs more often on the right than the left side. However, the tumor may herniate through the sciatic foramen and present posteriorly. The presenting complaint is usually constipation, although in one case dysmenorrhea and increase in the length of the menstrual periods were noted. Diagnosis is suggested by a history of lifelong constipation, palpation of a fluctuant retrorectal tumor, and demonstration of deformity of the sacrum by the x-ray. The treatment should be conservative unless symptoms become severe or the danger of the meningocele complicating pregnancy arises. The operation consists in exposing the tumor, ligating and sectioning its pedicle. It is not necessary to excise the wall of the sac because it does not secrete spinal fluid. It seems better to approach the tumor through a posterior midline incision than through an abdominal incision because it can be more easily visualized in this manner and there is less danger of damaging the great vessels, the pelvic organs, or the ureters.

SUMMARY

Anterior sacral meningocele is discussed, the literature reviewed, and a case with treatment described.

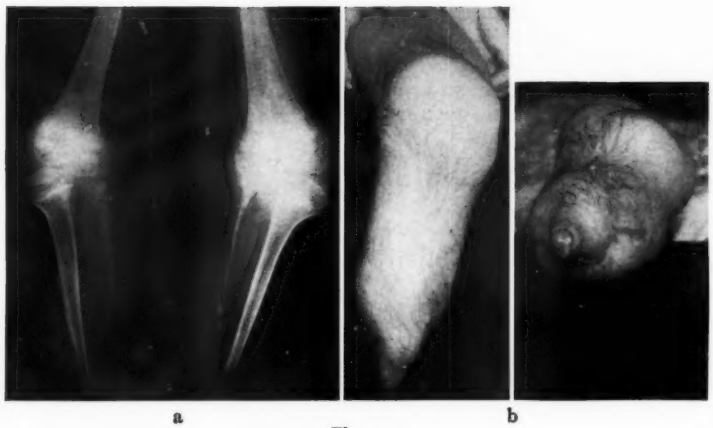
REFERENCES

1. "A Distinguished Surgeon," anonymous at his request, "as he was anxious the case should not be recognized by some parties to whom its publication might give pain." Case of deficiency of the anterior part of the sacrum, with a thecal sac in the pelvis, similar to the tumor of spina bifida. Reported to the Medical Society of London, November 27, 1837, Mr. Bryant presiding. Lancet, 1837, 1: 358–360.
2. BRYANT, T. Referred to by Buhl: Bericht ueber die Leistungen im Gebeite der Bildungsfehler und Foetalkrankheiten. Canstatt's Jahresb. Fortschr. ges. Med., 1858, 2: 24. Same case as in reference 1.
3. COQUI. Zschr. Geburtsh. Gyn., 1916, 78: 609–631.
4. DEMEL, RUDOLPH. Deut. Zschr. Chir., 1928, 209: 90–97.
5. DRENNAN, A. M. J. Path. Bact., Lond., 1929, 32: 843–844.
6. EMMET, T. A. Am. J. Obst., N. Y., 1871, 3: 623–631.
7. GROSSMAN, EMIL. Jahrb. Kinderh., 1906, 63: 224–234.
8. HOFMOKL. Medizinische Jahrbücher, 1878, pp. 443–466.
9. HUGENBERGER, THEODOR. Arch. Gyn., 1879, 14: 1–33.
10. KENNEDY, R. L. J. Surg. Gyn. Obst. 1926, 43: 803–804.
11. KRONER, TRANGOTT, and MARCHAND, F. Arch. Gyn., 1881, 17: 444–474.
12. LOHLEIN, H. Gynäkologische Tagesfragenol, 4: 32–46. Wiesvanden: J. F. Bergman, 1895,
13. LUTH, GEORG. Zbl. Chir., 1937, 64: 15–19.
14. NEUGEBAUER, FRANZ VON. Beitr. Geburtsh. Gyn., 1905, 9: 198–252.
15. NIEBERDING, WILHELM. Münch. med. Wschr., 1904, 51: 1384–1386.
16. PICK, B. P. Brit. M. J., 1929, 2: 46.
17. PUPOVAC, D. Arb. Geb. klin. Chir., 1903, 1: 533–549.
18. ROBINSON, H. B. Med. Press & Circ., Lond., 1903, 75: 477–478.
19. ROUX, SUZANNE. Rev. méd. Suisse rom., 1918, 38: 47–71.
20. SABATINI, LUIGI. Policlinico, 1927, 34: 254–265.
21. SANTY, P. Lyon. chir., 1938, 35: 446–448.
22. THOMAS, T. G. Gaillard's M. J., N. Y., 1885, 40: 237–242.
23. TULP, NICOLAES. Observations medicae. Amsterdam: Elzevir, 1652.
24. WEBER, E. Rev. fr. gyn. obst., 1921, 16: 377–392.
25. WILLARD, DE FOREST. Ann. Surg., 1904, 39: 612–615.



a b c d

Fig. 1.



a b

Fig. 2.

Fig. 3.

Fig. 1. a, Case 1, J. G. Preoperative x-ray film of right humeral stump at age of 10 years, April, 1931. b, Preoperative x-ray film at 13 years, March, 1934; 3 years after 1st reamputation. c, Preoperative x-ray film at 16 years, September, 1937; 3 years after 2d reamputation. d, Preoperative photograph showing bone protrusion, September, 1937.

Fig. 2. a, Case 7, L. P. Congenital amputation showing bone protrusion. Operative subperiosteal removal of fibula. b, Protrusion due to bone overgrowth. The bone is covered with granulations.

Fig. 3. Case 9, J. S. Bone protrusion. Note closing epiphyses.

Amputations in Children.—Frederick vom Saal.

AMPUTATIONS IN CHILDREN

FREDERICK vom SAAL, M D., New York, New York

ALTHOUGH amputations in children are not nearly so common as in adults; congenital deformities, osteomyelitis, and trauma often make them necessary. They are worthy of special attention because *amputations in children are different.* Apparently it has not been generally recognized that there is continued bone growth without equivalent soft part elongation which frequently causes unwieldy stumps, pain, and bone protrusion. These are so common that one should be impressed by the frequent necessity for reamputation.

The upper humeral, tibial, and fibular epiphyses are all centers of rapid growth, and each supplies more than 50 per cent of the growth of its bone. As the epiphysis is usually some distance proximal to the stump end, the blood supply remains intact following amputation, and therefore bone growth is not interfered with. On the other hand the lowered skin temperature and shrinkage around the end of the stump are evidence of muscle atrophy and diminished blood supply which probably reduces the soft part potential for growth. This may be the reason for the failure of soft part growth to equal bone growth. Commonly the bone is seen protruding from the soft parts but is still covered with tightly stretched skin. The next stage in the process is ulceration over the protruding bone. Eventually the bone perforates the skin, in which case soft granulations usually cover the bone.

In a series of tibial amputations seen by the author, 16 of 20 children had bone protrusion or painful long stumps with tightly stretched skin and soft parts (Table I). The cases observed include not only operative but also congenital amputations. Eight patients whose epiphyses were fused have had no difficulty with their stumps. In another series of cases it was found that only 5 of 20 femoral amputations had bone protrusion. This may be due to the very adequate thigh circulation and the relatively small amount of growth at the upper femoral epiphysis. Epiphysiodesis is therefore recommended as an adjunct to amputation in children in cases in which the section is through the tibia or humerus. This simple orthopedic procedure will prevent deformity by stopping further bone growth.

As can be seen in Table I, all patients, but Cases 1 and 20, were old enough so that an "ideal" stump length could be obtained at the time of original amputation. This is usually possible after the age of 6 years. Optimum tibial length varies between 4 and 7 inches. If this length can be obtained, further growth is certainly not desired as it will make the use of a prosthesis difficult and painful. Therefore, epiphysiodesis, in addition to preventing bone protrusion, maintains the "ideal" tibial length. It should have been performed on these 2 patients (Cases 1 and 20) at the time of first reamputation. We presuppose that the remaining epiphysis of the severed bone is still open. This should be determined by x-ray examination, as the upper tibial epiphysis, for example, not infrequently remains open until the patient reaches the age of 24 years.

Fusion of the upper tibial or fibular epiphysis is a very simple procedure adequately described elsewhere (2, 3). In primary amputations it is usually better to wait about 3 weeks before epiphysial fusion is performed. But reamputation and epiphysiodesis may easily be done in one stage.

The approach to the upper humeral epiphysis is not described in the usual texts. The author has used short anterior and posterior paradeltoid incisions. A large amount of cartilage should be removed with a curette and the arm kept in a swathe for 3 weeks.

There is also an economic factor involved in these cases. Stump growth usually requires rapid change of prosthesis in the case of children, whereas the changes which occur are much less frequent when the growth is entirely above the knee joint.

Occasionally amputation will be done in children so young that an "ideal" stump length cannot be obtained. In these patients epiphysial fusion may be delayed until the optimum length has been reached and in the hope that reamputation will not become necessary. The epiphysis should be fused, however, as soon as the optimum length has been reached.

SUMMARY

A résumé has been presented of 23 cases of amputation in children in which bone protrusion necessitated reamputation. The protrusion apparently was due to continued growth of an

TABLE I.—RÉSUMÉ OF 23 CASES OF REAMPUTATION*

Case	Sex	Site	Primary amputation		Reamputation		Comment
			Age	Reason	Age	Reason	
1. J.G.	Male	R. humerus	2	Severe burn	10 13 16	Bone protrusion Bone protrusion Bone protrusion	At each reamputation the stump was covered with a thick muscle pad
2. O.M.	Male	R. femur	11	Gas gangrene	16	Bone protrusion	Skin ulcer
3. R.G.	Male	L. tibia	9	Trauma	12	Bone protrusion	Epiphysiodesis
4. J.S.	Male	L. tibia	10	Unknown	16	Bone protrusion	Stump too long
5. D.S.	Male	R. humerus	13	Gunshot	18	Pain	Very tight skin
6. L.W.	Male	L. tibia	11	Trauma	14 17	Bone protrusion Tight skin	Pain and ulcer
7. L.P.	Female	R. tibia		Congenital	8	Bone protrusion	Fibula removed
8. J.D.	Male	R. femur	13	Unknown	18	Bone protrusion	Pain granulations
9. J.S.	Male	L. tibia	11	Trauma	16	Bone protrusion	
10. C.R.	Male	R. tibia	9	Congenital deformity	12	Growth	Stump too long epiphysiodesis
11. L.D.	Male	R. tibia	12	Trauma	19	Growth	Stump too long
12. M.R.	Male	R. tibia	9	Trauma	14	Bone protrusion	Pain, epiphysiodesis
13. C.H.	Male	L. femur	12	Trauma	18	Bone protrusion	Ulceration
14. J.H.	Male	R. tibia	14	Trauma	20	Pain	Skin pressure
15. N.C.	Male	R. femur	6	Congenital deformity	9	Pain, growth	Skin pressure, stump too long
16. L.G.	Male	R. tibia	14	Trauma	16	Pain, growth	Stump too long
17. A.B.	Male	L. tibia	13	Unknown	18	Pain	Tight skin
18. C.T.	Male	L. tibia	12	Trauma	18	Ulceration	Pain, stump too long
19. L.G.	Male	R. tibia	10	Unknown	15	Pain	Tight skin
20. D.P.	Male	R. tibia	5	Congenital pseudarthrosis	13	Bone protrusion	Pain
21. L.B.	Male	L. tibia	11	Congenital deformity	17	Pain	Tight skin
22. L.J.	Male	R. femur	7	Trauma	10	Pain	Tight skin
23. B.G.	Male	R. tibia	12	Unknown	16	Growth	Stump too long

*Cases reported through kindness of Dr. Paul C. Colonna of Oklahoma Crippled Children's Hospital and of Dr. Francis Carr of Hospital for Ruptured and Crippled of New York.

open epiphysis without compensatory soft part elongation.

After the age of 6 years an "ideal" stump length can usually be obtained. Further growth is not desired.

Therefore, epiphysial fusion has been recommended following amputation in childhood to prevent deformity, pain, bone protrusion, continued growth, and reamputation.

REFERENCES

1. KURTZ, A.D., HAND, R. C. Am. J. Surg., 1939, 43: 773.
2. PHEMISTER, D. B. J. Bone Surg., 1933, 15: 1.
3. VOM SAAL, F. H. J. Bone Surg., 1939, 21: 442.

PRIMARY CARCINOMA OF THE APPENDIX RESEMBLING CARCINOMA OF THE COLON

ALFRED UIHLEIN, M.D., and JOHN R. McDONALD, M.D.,
Rochester, Minnesota

MUCH has been written concerning epithelial neoplasms of the appendix (1, 3, 6, 10, 11, 12, 13), but there is still considerable confusion with regard to the classification of these tumors. A simple yet workable classification would divide carcinomas of the appendix into 3 types: first, carcinomas of the carcinoid type (5, 7, 8); second, carcinomas of the cystic type producing pseudomyxoma peritonaei (2, 4, 9, 14, 15); and third, carcinomas which resemble, both grossly and microscopically, those found in the colon and which will be referred to as the colonic type.

Our interest in the subject of carcinomas of the appendix of the colonic type was aroused by a recent case which emphasizes the importance of recognizing a carcinoma of this type.

REPORT OF CASES

CASE 1. The patient, a woman aged 69 years, had a 6 weeks' history of pain in the right lower quadrant with an occasional tarry stool. Two weeks previous to admission a mass was felt in the region of the cecum which was slightly tender yet movable. On examination a tender mass 3 by 4 centimeters in diameter was felt in the right lower quadrant of the abdomen. The leucocyte count was 11,200 in each cubic millimeter of blood. On roentgenological examination of the colon, the tip of the cecum was deformed by pressure apparently from what seemed to be an extrinsic mass. At operation the appendix was found to be very large. Examination of the appendix disclosed a polypoid mass which involved the proximal 4 centimeters of the mucosa (Fig. 1). Histological examination by the fresh frozen section technique disclosed an adenocarcinoma, grade 1—Broders' method—(Fig. 2), which had not yet begun to invade the musculature. This carcinoma was forming considerable mucus and was comparable both grossly and microscopically to those seen in the colon. In addition there was an inflammatory perforation of the tip of the appendix with periappendicitis. Because of the wide distribution of the carcinoma on the mucosa at the base of the appendix, the portion of the cecum surrounding the opening of the appendix was excised. No carcinoma was found in this specimen. The opening in the cecum was closed. The patient had an uneventful convalescence except for a slightly tender mass which could be felt through the abdominal wall lateral to the anterior iliac spine. On the 12th postoperative day this subsided under treatment with diathermy. The patient was dismissed from the hospital on the 21st postoperative day with the wound healed by primary union. Nine months later she was living and well.

From the Division of Surgery, Mayo Foundation and the Section on Surgical Pathology, Mayo Clinic.

A search of our files supplemented by further microscopic examination of suspected specimens disclosed that in the period from 1910 to 1941, inclusive, a diagnosis of carcinoma of the appendix had been made on 144 specimens removed at operation. Of this number 127 (88.2 per cent) of the carcinomas were of the carcinoid type, 12 (8.3 per cent) of the cystic, and 5 (3.5 per cent) of the colonic type. Only 5 specimens of primary adenocarcinoma of the appendix of the colonic type had been removed at operation. This includes the case which has been cited. A brief summary of the additional 4 cases follows:

CASE 2. The patient, a woman aged 36 years, 6 months before had had two attacks of abdominal pain in the right lower quadrant with vomiting and fever. Each attack required morphine. During this period blood was passed in the stools. On examination there was found generalized abdominal tenderness. A roentgenogram of the colon showed an incompetent ileocecal valve with dilatation of the cecum. At operation a leiomyoma of the uterus was removed together with the appendix.

On gross examination, the distal 1 centimeter of the appendix was obliterated. Proximal to this obliteration in the middle third of the appendix was a tumor 1.3 by 0.5 by 0.5 centimeter. This disclosed histologically an adenocarcinoma, grade 1, which had involved the mucosa, submucosa, and musculature and also was forming good acini and much mucus.

The postoperative course was uneventful. Ten years later the patient was alive and well and abdominal hysterectomy did not disclose any evidence of the presence of carcinoma.

CASE 3. The patient was a man, aged 60 years. Two months prior to admission, he had had generalized abdominal pain. One week after admission, he had pain in the right lower quadrant of the abdomen with elevation of temperature. There was no blood in the stools. A roentgenogram of the colon showed a deformity in the medial aspect of the cecum displacing the ileum toward the midline, suggesting a pericecal granuloma. The leucocyte count was 10,800 in each cubic millimeter of blood. At operation a tumor was found at the base of the appendix and cecum with much secondary inflammation. Ileocolostomy was done and 3 weeks later resection of the right portion of the colon was performed. The gross specimen consisted of 7 centimeters of ileum, 8 centimeters of cecum and the appendix. An adenocarcinoma, grade 1, was found at the base of the appendix extending into the cecum (4 by 3 cm.). The lymph nodes were not involved. The patient had an uneventful convalescence. Three and a half years later, the patient was living and well.

CASE 4. The patient, a woman aged 50 years, had pain in the upper part of the abdomen for several months requiring morphine 2 or 3 times a week. On examination,

Fig. 1.

Fig. 1. Papillary adenocarcinoma, grade 1, of the appendix of the colonic type. This gross specimen was removed in Case 1.

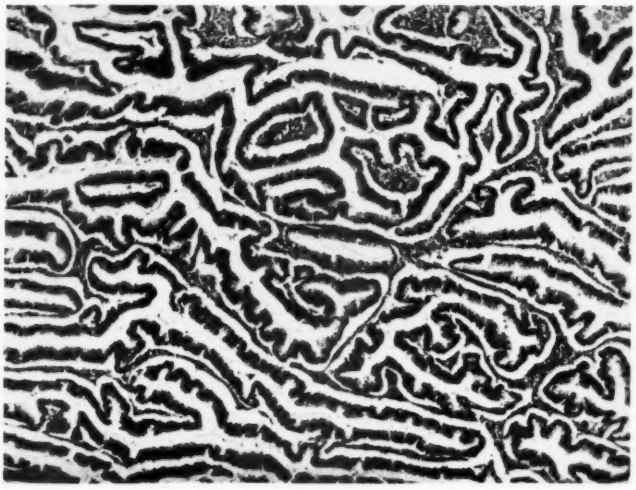


Fig. 2.

Fig. 2. Section of papillary adenocarcinoma of the appendix. Well formed acini in which papillary projections are evident (Case 1). Hematoxylin and eosin stain, ×45.

there was found tenderness, particularly on the right side. A normal leucocyte count was obtained. A roentgenogram revealed a poorly functioning gall bladder with stones. At operation cholecystectomy and appendectomy were done. There were no other demonstrable lesions in the abdomen. The gall bladder disclosed the presence of chronic cholecystitis with stones.

On gross examination of the appendix, the lumen was found to be dilated, and in its tip was a polypoid tumor 1.1 centimeters in diameter. This revealed a mucus-producing adenocarcinoma which was graded 1 because of the differentiation into well formed glands. The postoperative convalescence was uneventful. Four years later the patient was alive and well.

TABLE I.—COMPARISON OF THE THREE TYPES OF CARCINOMA OF THE APPENDIX

	Carcinoid type	Cystic type	Colonic type
Location	Usually tip	Tip or base	Tip or base, more frequently base
Incidence	89 per cent	8 per cent	3 per cent
Gross character	Yellowish solid	Cystic, frequently on basis of a mucocele	Grayish, polypoid or ulcerating
Microscopic structure	Poorly formed acini, mucosa intact over tumor. Reduction of silver salts, affinity for chrome salts	Papillary projections originating in cyst. Comparable to cystadenocarcinoma of ovary. Epithelial cells few because of destruction by mucus	Frequently well formed acini; mucous membrane ulcerated. Comparable to carcinoma of colon
Mitoses	Few	Few	Variable
Mucus	None	Secretes large quantities	Secretes variable quantities
Metastasis	To regional nodes in less than 1 per cent	So called pseudomyxoma peritonaei	To lymph nodes and liver

Case 5. The patient was a man, aged 46 years. He had had epigastric distress (periodic for 20 years) relieved by soda. Examination revealed epigastric tenderness. A roentgenogram of the stomach and duodenum disclosed a duodenal ulcer. The leucocyte count was 10,700 in each cubic millimeter of blood on admission. At operation, a duodenal ulcer was found, and partial gastrectomy was performed. Routine appendectomy was done. Examination of the stomach and duodenum revealed mild gastritis and duodenitis. Within the lumen of the appendix there was a 5 millimeter projection which revealed an adenomatous polyp showing early adenocarcinoma, grade 1 (Figs. 3 and 4). The patient had an uneventful convalescence and was dismissed from the hospital on the 13th postoperative day. A year later he was in good health.

There are several salient features about this type of neoplasm in the appendix which are outstanding and worthy of note. On gross examination the lesions may be either polypoid or ulcerative just as are carcinomas of the large bowel. Because of their frequent location in the base of the appendix, obstruction to the appendiceal lumen usually results early in the course of the disease. As a consequence, acute appendicitis—usually with perforation—is a common occurrence. This results in early operative intervention with removal of the diseased appendix including the carcinoma. It follows naturally that the prognosis is better than it is in carcinoma of the colon

because the lesions are smaller when they are removed.

Histologically, this carcinoma may be differentiated, producing well formed glands. On the other hand, the carcinoma may be quite undifferentiated and produce signet-ring cells. Usually variable amounts of mucus are produced by the neoplastic cells. Extra care is needed in the excision of this type of carcinoma of the appendix because such a neoplasm frequently involves the base of the appendix, occasionally extending into the cecum. If this is so, a more extensive resection may be necessary which would include a portion of the cecum.

Some, at least, of the colonic type of carcinoma originate on the basis of adenomatous polyps, as suggested by Case 5 in which there was carcinomatous change in an adenomatous polyp. The histogenesis appears to be comparable to that of a carcinoma of the colon. It is a well recognized fact that several carcinomas are likely to appear in the colon at the same or different times. For this reason greater care should be taken in the following up of this type of carcinoma of the appendix with special reference to the possible development of a carcinoma in some part of the colon or rectum.

The symptomatology which is found in this type of lesion appears to be twofold. Symptoms of the first group are referable to obstruction of the appendiceal lumen with or without acute inflammatory changes in the appendiceal wall distal to the lesion. These symptoms may be exaggerated by perforation of the appendix. Symptoms of the second group are caused by the ulceration of the lesion with bleeding. The result is manifest by tarry stools.

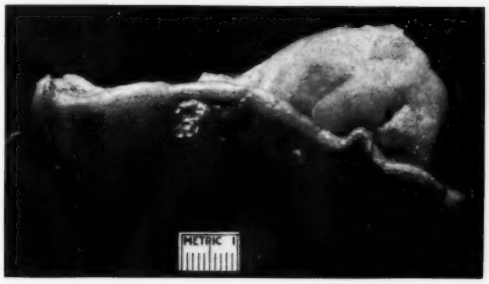


Fig. 3. Interior of the appendix showing an adenomatous polyp.

A comparison of some of the more important points of differentiation between the three types of carcinoma of the appendix is set forth in Table I. Figures 5 and 6 represent the characteristic microscopic findings present in the carcinoid and cystic types.

Fig. 4.

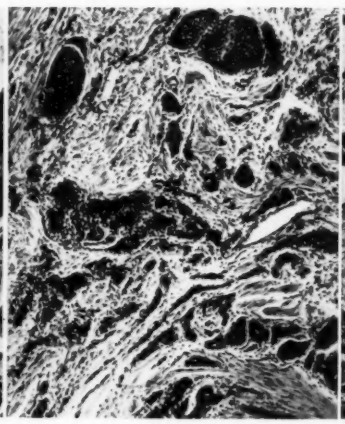


Fig. 5.

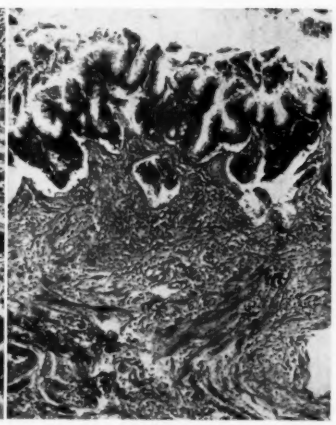


Fig. 6.

Fig. 4. Section of an adenomatous polyp in the appendix. Regions of malignancy are characterized by larger deeper staining nuclei as contrasted with the benign regions which show paler smaller nuclei. This lesion is in every way comparable to a carcinomatous polyp in the colon. Hematoxylin and eosin stain, ×55.

Fig. 5. Adenocarcinoma of the appendix, grade 1, of the carcinoid type. The groups of small cells with deeply staining nuclei are apparent with very little evidence of formation of glands. Hematoxylin and eosin stain, ×57.

Fig. 6. Intracystic papillary adenocarcinoma, grade 1. The papillary projections and the beginning infiltration into the wall of the appendix are to be seen. This type of neoplasm when it spreads to the peritoneum produces pseudomyxoma peritonaei. Hematoxylin and eosin stain, ×85.

SUMMARY AND CONCLUSIONS

Primary carcinomas of the appendix may be divided into three types: (1) carcinoid type, (2) cystic type, producing pseudomyxoma peritonaei, and (3) colonic type. Five cases of the colonic type of carcinoma of the appendix have been presented and described. A table has been compiled to present the characteristic features in each of the 3 types of carcinoma of the appendix.

REFERENCES

1. Berger, A. Berl. klin. Wschr., 1882, 19: 616–618.
2. Chaffee, J. S., and LeGrand, R. H. Arch. Surg., 1942, 45: 55–73.
3. Elting, A. W. Ann. Surg., 1903, 37: 548–574.
4. Hall, D. P. South. Surgeon, 1941, 10: 264–270.
5. Hasegawa, Tomoo. Virchows Arch., 1923, 244: 8-37.
6. Heine, J. Zbl. Chir., 1935, 62: 2601–2603.
7. Hopping, R. A., Dockerty, M. B., and Masson, J. C. Arch. Surg., 1942, 45: 613–622.
8. Latimer, E. O. Am. J. Surg., 1941, 54: 424–430.
9. Masson, J. C., and Hamrick, R. A. Surg. Gyn. Obst., 1930, 50: 1023–1029.
10. Schuldt, F. C. Minnesota M., 1940, 23: 791–795.
11. Selinger, J. Ann. Surg., 1929, 89: 276–281.
12. Vance, C. A. Am. J. Surg., 1934, 24: 854–862.
13. Wakeley, C. P. G. Practitioner, Lond., 1936, 137: 733–739.
14. Waugh, T. R., and Findley, David. Am. J. Surg., 1937, 37: 518–525.
15. Woodruff, R., and McDonald, J. R. Surg. Gyn. Obst., 1940, 71: 750–755.

INFILTRATION THERAPY OF ACUTE TENDINITIS WITH CALCIFICATION

PAUL W. LAPIDUS, M.D., F.A.C.S., New York, New York

THE first descriptions of acute tendinitis with calcification were concerned with its occurrence at the shoulder joint. It was not until later, with the development of roentgenology, that it became possible to diagnose its existence in other locations, where its similarity linked it with the condition found in the shoulder.

A review of the literature on this subject indicates that the earlier investigators were not in a position to make a precise differential diagnosis of the multiple periarticular lesions of the shoulder joint. Therefore, their interpretations were often erroneous and their diagnoses inaccurate.

In the beginning of the nineteenth century Cowper, and later others, attributed most of the posttraumatic lesions of the shoulder to dislocation of the tendon of the long head of the biceps. Jarjavay, in 1867, denied the existence of dislocation of the biceps tendon and concluded that bursitis was misdiagnosed as a tendinous dislocation. On the basis of a few clinical cases and also anatomical dissections, he gave a rather precise description of bursitis at the shoulder. One of his patients had serous effusion in the bursa and was treated by repeated evacuation of the fluid by means of "puncture with a bisturi."

In 1872 there appeared the classical work of Duplay, who described a new clinical entity, which he called "périarthrite scapulo-humérale," later named after him, "morbus Duplay." Most of Duplay's cases were posttraumatic, and it is evident that his "périarthrite scapulo-humérale" included fractures, tendinous tears, tendinitis with calcification, bursitis, periarticular changes, which we now classify as "frozen shoulder," and probably also many other diseases of the shoulder.

Before Duplay, a great number of shoulder lesions were considered due to "rheumatism." In his first cases Duplay suspected intra-articular fibrous ankylosis because of the cracking sound produced during manipulation under chloroform. A postmortem examination performed in 1870 on one of his patients, whose shoulder had been manipulated under anesthesia because it was stiff following a reduced dislocation, proved to him that the changes were periarticular, and not a true intra-articular ankylosis. Of especial interest is the following conclusion of Duplay: "In fact, one can admit that there exists besides the scapulohumeral joint itself a second articulation between the inferior surface of the acromiocoracoid vault and the upper end of the humerus, which is covered by its periosteum and by the tendons inserting themselves over the tuberosities. All the motions of the scapulohumeral joint are associated with corresponding mobility in this second articulation which is located externally to the first; in other words, the upper end of the humerus glides beneath the acromioclavicular vault."

Fifty-six years later, Codman (1934) likewise considered the subacromial bursa "in fact a secondary scapulohumeral joint."

Duplay's treatment consisted of manipulation under chloroform followed by exercises. In 1878 Despates described his experiences with "morbus Duplay." He emphasized that periarthritis is not exclusively a local lesion of the bursa, but rather a manifestation of generalized *diathèse rheumatic*. He reported 2 cases in which he stressed the simultaneous arthritic involvement of the other joints, muscular atrophy, tender brachial plexus, and other trophic changes. One of his patients apparently also had severe herpes zoster over the shoulder and the back. The treatment of Despates, however, was the same as that of Duplay, and likewise consisted of repeated manipulations under chloroform.

Putnam, in 1882, introduced "morbus Duplay" into Boston. He did not quite agree with Duplay's view that manipulation is the only rational therapy, since one of his patients recovered after being "left entirely to himself." Nevertheless, most of his patients were subjected to manipulation under ether. This procedure became the routine treatment in Boston, until the early days of Codman.

With the advent of roentgenology it became possible to observe periarticular shadows at the shoulder joint, which were thought to be fractures. During the first years of the twentieth century the designation "périarthrite scapulo-humérale" no longer satisfied the clinician. At-

From the Hospital for Joint Diseases, Service of Leo Mayer, M.D.; and the New York Polyclinic Medical School and Hospital, Service of J. J. Nutt, M.D.

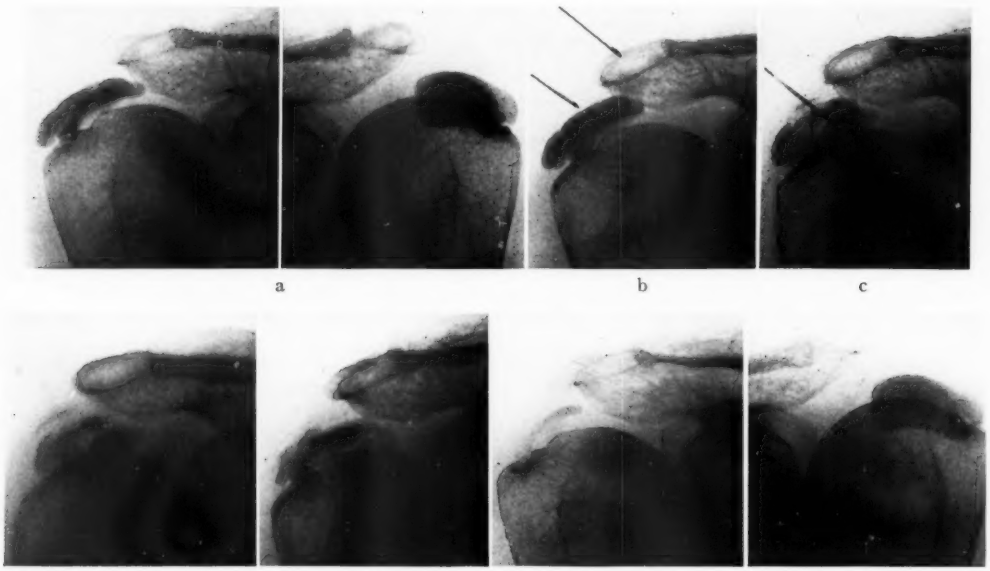


Fig. 1. Case 2, L. L. a, Roentgenogram of both shoulders taken on May 11, 1942, showing a large dense calcareous deposit in both shoulders. b, Shows that the point of the first needle was incorrectly introduced (upper needle), striking the acromion. The second needle was properly inserted, pointing toward the center of the calcareous deposit, but its point did not quite reach it. c, X-ray picture immediately after aspiration of 0.5 cubic centimeter of calcareous material. Note that the point of the needle now rests in the center of the deposit, and the large calcareous material is still demonstrable in spite of aspiration and infiltration treatment. However, it appears to be motheaten and spread over a somewhat larger area, as compared with the film, a, prior to aspiration and infiltration therapy. d, X-ray picture 3 days after the infiltration therapy. Note the fragmentation of the calcareous deposit, which appears to be motheaten and spread over a wider area. e, X-ray picture 3 weeks after the infiltration therapy shows further spreading and fragmentation of the calcareous deposit. f, X-ray pictures of both shoulders 2 months and 5 days after the operation. Note practically complete disappearance of the deposit on the right treated side and no change over the left shoulder which was treated only with physical therapy.

tempts were made to discard "morbus Duplay," and to consider what was once diagnosed "périarthrite scapulohumérale," a periarticular fracture which Duplay and his contemporaries were unable to diagnose.

Pourtin, in his doctorate thesis (1902), entitled "About the Unknown Partial Fractures of the Upper End of the Humerus in the So-Called Primary or Secondary Periarthritis of the Shoulder," recorded 13 cases with fracture of the greater tuberosity, all of which were diagnosed as "morbus Duplay" before roentgenograms were taken. Pourtin expressed considerable doubt about the existence of bursitis, whether as a primary lesion or of posttraumatic origin, and thought that all these cases represented fractures. Obviously his teachers, Testut and Jacob, must have shared his opinion. The tendency to recognize fractures was so prevalent at this time that probably the calcareous deposit was also mistaken for a fracture.

In 1904 Codman called the term periarthritis "a sort of surgical wastebasket in which we throw our diagnostic failures." Two years later, he described the anatomy of the subdeltoid bursa, and opined that subdeltoid bursitis is far more common than any other lesion of the shoulder. Strangely enough there was no mention of the calcareous deposit in this article, although reference was made to the fact that frequently there was "evidence that a chip of bone was torn from the tip of the tuberosity at the point of insertion of the supraspinatus."[1]

Several cases in which open operation had been performed were included in his paper. One (operated upon by Dr. F. B. Harrington) yielded "staphylococcus bearing pus." In a chronic case straw-colored fluid was present. Two patients were found to have a "split in the capsule between

[1]Codman must have been aware of the existence of the deposit, since he was present at the operation upon Painter's patient in May, 1905.

a b c

d

Fig. 2 Case 3, H. F. a, Roentgenogram of right shoulder with needle in center of the deposit before infiltration therapy. Note the presence of a deposit also over the left shoulder, a, right, which was completely symptom free at that time. b, Roentgenogram of right shoulder 5 days after infiltration therapy. Note fragmentation and spreading of the deposit over a much larger area and beginning of absorption. c, Roentgenogram of right shoulder 4 months after infiltration therapy. Note practically complete disappearance of the deposit. d, Roentgenogram of right shoulder, 1½ years after infiltration therapy. Note complete disappearance of the deposit on the right side. X-ray picture of the left shoulder taken at the same time showed the same findings as in a, at right.

the tendons of the supraspinatus and infraspinatus." This tendon rupture was also noted in 5 cadavers. Intrabursal fibrous bands and adhesions were often observed both at operations and also in anatomical material. Careful dissection on one cadaver showed "that the subdeltoid adhesions alone maintained the limitation of abduction and external rotation."

Painter (1907) seems to have been the first to report operative findings in a case of acute periarticular calcification at the shoulder diagnosed roentgenologically before the operation. The patient, a physician, 37 years old, was operated upon in the presence of Codman on May 17, 1905. The calcareous material was removed, and the patient sustained prompt relief. The operative findings were also given in 3 other similar cases. The deposit consisted mainly of calcium phosphate, also calcium carbonate, and traces of magnesium.

In 1908 there appeared another very extensive paper by Codman, based on observations of 75 painful shoulders. The term "subacromial" was offered as a substitute for "subdeltoid," and it was

a b c d

Fig. 3. Case 17, R. M. a, Roentgenogram of left elbow showing tear-shaped calcareous deposit (arrow) near lateral epicondyle. Note that the shadow is rather small and well outlined. b, Roentgenogram of same elbow 2 months later during very acute stage, showing considerable increase in the size of the deposit, which also became more diffuse. c, Same elbow 2 weeks after infiltration therapy shows only slight traces (arrow) of the deposit, which is hardly noticeable and spread over a wide area. d, Same elbow 1 month after infiltration therapy shows complete disappearance of deposit.

Fig. 4. Case 23, G. G. a, left, Roentgenogram of the trochanter of the left femur during acute stage, showing large hazy calcareous deposit (arrow). b, X-ray picture 8 days after infiltration therapy shows complete disappearance of the deposit simultaneous with marked relief of local symptoms.

emphasized that only one large bursa is normally present. Apparently roentgenograms were taken in only a very few cases in this series. Likewise, in the article published in 1908, Codman again paid comparatively little attention to the periarticular deposit. From Codman's case reports it may be surmised that in several patients acute calcified tendinitis might have been overlooked.

Nevertheless, from the findings in Painter's case and in another patient with calcareous deposit which was operated upon by him on May 25, 1908, Codman (1908) made the important observation that the deposit was "not in the bursa, but beneath its base, and in or adjacent to the tendon of the supraspinatus." Although most of Codman's patients were still treated by manipulation under anesthesia, he seemed to favor open operation in selected cases.

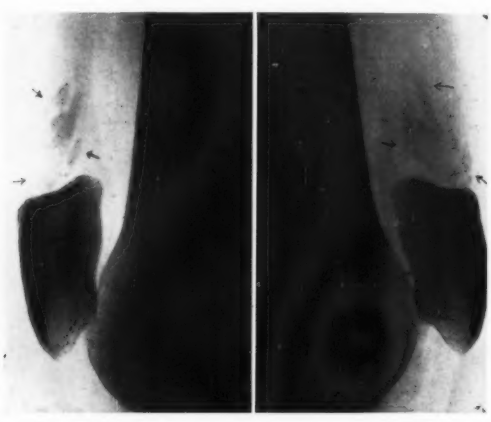


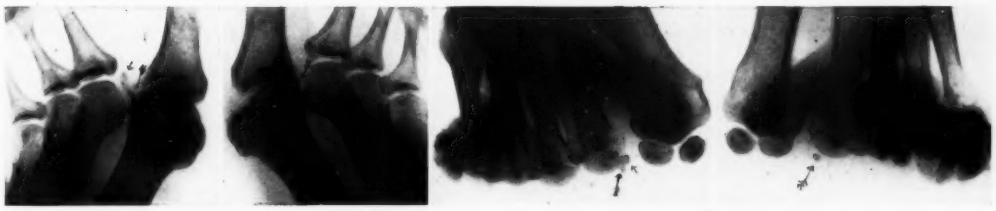
Fig. 5. Case 26, C. S. Roentgenograms of both knees showing large, irregular, hazy calcareous deposits (arrows) in the rectus femoris tendon on both sides.

In 1911 Codman recorded two more operations in patients with periarticular calcification discovered by roentgenograms. These further substantiated the intratendinous location of the deposit. In one conservatively treated patient inflammation of the bursa was thought to be caused by a "rupture of the wen-like sack" into the bursal cavity.

Stieda, in 1908, had regarded the deposit as a result of gout of the bursa. At the end of the same year, however, Bergemann and Stieda found no evidence of uric acid in 3 patients who had acutely painful shoulders upon which operation had been performed.

Excellent reproductions of the roentgenograms of 6 patients with calcareous deposit at the shoulder were given by Haenisch in 1910. In 1 case excision of the bursa was performed, with recurrence of the deposit. Wrede, in 1912, reported an open operation in a man 76 years old, in whom he found the deposit in the tendon, but not in the bursa.

A series of shoulders in 18 of which open operation was performed was reported by Brickner in 1917. This investigator likewise stressed the intratendinous location of the deposit. Like



a b

Fig. 6. Case 31, K. B. a, Oblique view of both feet showing normal inconstant second tibial sesamoid (arrow) on the right side (at right). The left second tibial sesamoid (large arrow in left film) is surrounded by calcareous deposits (small arrow), which spread toward the base of the proximal phalanx. b, Special sesamoid technique showing the inconstant second tibial (large arrow) on both sides. Note the calcareous deposits (small arrows) around the sesamoid on the left side (film at left).

Codman, Brickner considered that the subacromial and the subdeltoid bursa were one and the same.

The results of the pathological examination of the tissue removed by Brickner in 4 cases were presented by Moschcowitz in 1915. He found the lesion to be intratendinous, and thought that "calcification only occurs in dead or inert tissue, that is, tissues that have no blood supply. It never occurs in tissues whose blood supply is abundant."

Numerous investigators, including Carnett (1925), Ayzac (1926), Elmsie (1932), and many others, have contributed to our knowledge of acute calcified tendinitis. Schaer (1936) published a large work with an extensive bibliographical review. Sandstroem and Wahlgren (1937) gave pathological findings in 12 cases in which open operation had been performed. Roentgen therapy was used by Sandstroem (1938) with apparently favorable results in a number of cases. There was no mention of infiltration treatment.

Richards, in 1931, accidentally discovered that intravenous injections of iron cacodylate relieved acute painful shoulders. His 3 reported cases are, however, not convincing.

The first report of prompt relief of symptoms by aspiration under local anesthesia was that of Flint, of Yale, in 1913. Two patients with acute shoulder lesions were promptly relieved by this treatment. In both cases, 3 to 4 cubic centimeters of straw-colored fluid, which was sterile and coagulated on standing, was obtained.

A year later, Sievers (1914), in Germany, cognizant of Flint's publication, described the case of another patient similarly treated, with success. No roentgenographic findings were given. Weeks and Delprat, in 1936, claimed that in 1908 a patient with acute painful shoulder was promptly relieved after aspiration of 2 cubic centimeters of straw-colored fluid. They advocated multiple "needling" under local anesthesia, which gave them good results also in cases without calcareous deposit. The "needling" treatment has been used successfully by these investigators in additional cases treated after 1933.

Haldeman and Soto-Hall, in 1935, referring to cases of acute shoulder lesions, stated that they "have made it a practice to inject from 10 to 15 cubic centimeters of 1 per cent procaine hydrochloride into the bursa." Relief of pain and frequently disappearance of the deposit were obtained within a few days, but repeated injections sometimes were necessary.

Treatment of acute subacromial bursitis by open exploration or novocain injection was employed by Haggart and Allen in 1935, who stated: "Of the above two methods the most dramatic in its relief is that of exploration and drainage." The injection treatment was first attempted by these workers in 1934. Although favoring the open operation, they admitted that the novocain injection treatment "was strikingly helpful" in all cases of acute bursitis.

In 1938 Ferguson wrote that the novocain injection method has come "into favor during the past few years."

Patterson and Darrach, in 1937, described a method of removing the deposit by means of washing the bursa through two needles inserted into its cavity. Later, Patterson and Patterson (1940) reported further experience with this method. In 2 per cent of their cases general anesthesia was employed. Sometimes it was necessary to insert 3 or 4 needles "if a good flow was not obtained between the first two." The authors admitted that their original intention to wash out the deposit was apparently not always successful. However, relief was obtained, despite the fact that the "x-rays have sometimes shown apparently the same amount of calcium after the irrigation as before."

The use of novocain injection treatment in a case of a very acute lesion of the shoulder with a large deposit (treated in June, 1937) was reported by Leriche and Jung in 1938. The injection of 10 cubic centimeters of 1 per cent novocain, repeated every 12 hours until a total of 3 injections had been administered, enabled the patient to resume his work on the 4th day. At the end of the treatment the calcareous deposit was still present, but several months later it had disappeared.

From their experience in this case, Leriche and Jung offered "a new procedure," in addition to the 2 methods used until then—x-ray radiation and surgical removal of the deposit. It is evident from their article that as late as 1938 the French orthopedists were not familiar with the injection therapy of acute calcareous tendinitis.

Washing of the bursa or surgical drainage for the relief of "acute fulminative bursitis" was also practiced by Rogers in 1939.

In 1934 Milgram introduced actual aspiration of the calcareous material under local anesthesia, and for the past several years he has accumulated a very large number of cases, in most of which he was able to obtain the deposit by this procedure. Most of Milgram's patients experienced prompt relief.

The author, attempting to follow Milgram's method of aspiration in cases of acute tendinitis with calcification, was quite often unable to aspirate any calcareous material, and yet the prompt relief of pain and recovery were very often spectacular after simple infiltration with novocain solution.

In one of the cases (Case 7, M. A.) presented herein, the author, and also Milgram, failed to aspirate any calcareous material, despite persistent attempts. The patient, however, at once was greatly relieved by infiltration therapy from the excruciating pain, which was present for 16 days prior to the unsuccessful attempt at aspiration, and slept well the very first night after it.

Based on this experience and a number of other similar cases in which patients were treated successfully by infiltration, the writer has come to the conclusion that aspiration, with actual removal of the deposit, does not seem to be essential for relief of pain in acute cases. Besides, repeated postoperative roentgenograms at regular intervals showed the disappearance of the deposit within several weeks in most of his patients treated by infiltration only. On the other hand, the deposit, or at least a greater part of it, was still present after aspiration (Milgram), or even after washing of the deposit (Patterson and Patterson). This must have occurred frequently also in the cases of Patterson and Patterson for they "no longer make a point of taking x-ray pictures immediately after irrigation to see if the calcium has been completely washed out." Furthermore, there appears to be no justification for insisting on complete removal of the calcareous material in acute cases, since the immediate, and also the late results, have been just as good in cases in which thorough washing out of the deposit was considered essential or in cases of other observers, including the series reported here, in which only simple infiltration was performed.

INFILTRATION THERAPY OF ACUTE CALCIFIED TENDINITIS

The present day infiltration technique used by the author is as follows: The tender spot[1] is infiltrated with 10 to 20 cubic centimeters of 1 per cent novocain solution. The point of the needle is inserted close to the cortex of the head of the humerus and then withdrawn 3 or 4 millimeters. Control roentgenograms are taken with the needle *in situ* to make certain that its point is in the deposit. After adequate analgesia has been obtained, 30 to 60 or more cubic centimeters of warm normal saline solution are slowly infiltrated into, and close around, the deposit. The piston of the syringe is withdrawn several times in an attempt to aspirate the calcareous material. If this is not successful, then no further attempt is made.

The treatment is frequently followed by an increase of pain for the first 24 hours to 2 or 3 days. The patient is encouraged to practice stooping exercises and to limber up the shoulder in a warm bath. Adequate sedatives are administered the first few days if necessary. After the initial postoperative aggravation of pain, relief is obtained, as a rule, within a few to 48 hours; in a few cases immediate relief occurs without any initial increase of pain, and in a few the pain persists for 3 to 4 days. At first, the mobility of the shoulder is impaired, but motion is restored within 2 or 3 days to 2 weeks, and the patient is able to resume his work.

REPORT OF CASES

Although the conclusions expressed in this paper are based upon a much greater number of cases studied, only a limited number is reported herein. These, for the most part, have a detailed history, including x-ray findings and follow-up a year or more after the first visit. In all, 34 pa-

[1]When infiltration therapy is used in cases of acute calcified tendinitis in locations other than the shoulder, the same technique is employed, but the amount of the solutions used varies according to the extent and depth of the lesion.

tients are included in this report. These may be grouped as shown in Table I.

Table II gives an analysis of the 34 cases. In only 2 of the 16 shoulder cases was it possible to aspirate some of the calcareous material, although attempts were made in 15 of the cases. Moreover, in 1 case, although the calcareous material was obtained the decrease of the deposit progressed slowly, and the early functional result was poor. This, however, should be attributed more to the chronicity of the condition in this patient who had a large dense deposit present for many years with only mild symptoms.

Of the 16 shoulder cases, 12 were followed up from 1½ to 3 years after their first visit; in 4 no late follow-up could be obtained. Of the 12 cases in which the late result is known, 11 were classified as excellent (including 1 case in which recovery was spontaneous without infiltration therapy) and 1 as good.

Of the 6 cases with tendinitis at the elbow (Table II), it is interesting to note that in 4 identical cases infiltration therapy and likewise operative removal of the deposit gave excellent results. Relief of symptoms with some diminution of the deposit was also obtained in 1 case in which physiotherapy and immobilization were used, and in 1 case in which aspiration of some of the calcareous material was successfully done.

Cases of tendinitis in various other locations (Table II), include 3 at the hip, 4 at the knee, 1 at the wrist, and 4 at the foot. One case (hip) is interesting because of the apparent causal relationship between trauma and onset of the symptoms. The prompt recovery in this patient, including the complete disappearance of the deposit within a week after the infiltration was also noteworthy.

In 1 case there was bilateral acute tendinitis of the rectus femoris tendon with simultaneous secondary synovitis with effusion in the knee joint. In spite of the persistence of the deposit, with only slight diminution on the side treated by infiltration, the impression was gained that the infiltration therapy was followed by more prompt relief of symptoms than occurred on the other side treated by physiotherapy.

One patient (foot) presented an extremely unusual and interesting picture, both with respect to diagnosis and therapy. It is regrettable that it was not possible to try infiltration therapy in this case, since the author believes that it might have given excellent results without the necessity of resorting to open operation.

From the cases presented in Table II it is evident that the infiltration treatment was particularly successful in patients with acute calcareous tendinitis. It was also tried in a few cases of acute painful shoulder with severe localized tenderness, but without calcareous deposit. In some of these cases, relief was just as prompt as in those with a deposit. This procedure was of no benefit in cases of "frozen shoulder" without calcification, and consequently, it has been discontinued for treating this condition. It has not been tried in patients having a deposit without symptoms.[1] It is interesting to note that in the author's experience the roentgenograms taken routinely in patients with typical "frozen shoulder" showed no calcareous deposit, except in 1 or 2 instances. On the other hand, all the patients with acute calcareous tendinitis regained full range of scapulohumeral motion after the acute stage subsided, regardless of whether they were treated or left alone. It is suggested that the infiltration therapy be used mainly in patients with acute

TABLE I.—DISTRIBUTION OF CASES OF TENDINITIS WITH CALCIFICATION ACCORDING TO LOCATION OF LESION

Location of lesion	Number of patients	Total
Shoulder		16
1. Bilateral, with calcification	4	
2. Unilateral, with calcification	10*	
3. Acute bursitis without calcification	2	
Elbow		6
1. Lateral epicondylitis with calcification	5	
2. Tendinitis of triceps humeri with calcification	1	
Hip		3
Tendinitis with calcification of gluteus medius	3	
Knee		4
1. Calcification over the medial condyle of the femur	3	
2. Bilateral calcification of rectus femoris tendon	1	
Wrist		1
Calcification at the pisiform bone (unilateral)		1
Foot		4
1. Calcification in the tendon of peroneus longus near the peroneal bone (bilateral)	2	
2. Calcification in the lumbrical and interosseal tendons close to the sesamoid of the second toe (unilateral)	1	
3. Calcification in the Achilles tendon	1	
Total		34

*One patient (Case 14, E. G.), on examination on May 25, 1942, was found to have calcification in the opposite shoulder, making this a bilateral case.

[1] In 1 case the infiltration treatment with aspiration of the calcareous material resulted in practically complete disappearance of the deposit 2½ months later. Despite the roentgenological improvement, clinically the patient did not appear to be benefited. The case is still being followed, but the impression is gained that in chronic cases with mild symptoms the infiltration treatment should be used discriminately.

TABLE II.—ANALYSIS OF 34 CASES OF TENDINITIS WITH CALCIFICATION AT VARIOUS LOCATIONS

Factor	Site of tendinitis						
	Shoulder	Elbow	Hip	Knee	Wrist	Foot	Total
Number of patients	16	6	3	4	1	4	34
Sex							
Male	10	3	2	2	1	2	20
Female	6	3	1	2	.	2	14
Age in years							
25	..	.	.	1	.	.	1
30–35	..	1	1	.	1	1	4
36–39	1	.	.	.	.	.	1
40–45	5	.	.	.	.	1	6
46–49	5	3	.	.	.	.	8
50 and over	5	.	.	3	.	.	8
Unknown	..	2	2	.	.	2	6
Side affected							
Right	8[1]	3	.	1	1	1[9]	14
Left	4	2	1	2	.	1[10]	10
Bilateral	4	.	.	1	.	2	7
Unknown	..	1	2	.	.	.	3
Nature of symptoms*							
Acute	12	6	3	3	1	2	27
Chronic	4	.	.	1	.	2	7
Clinical findings							
Localized tenderness	16	3	1	3	.	1	24
Painful and limited motion	15	4	1	1	.	.	21
Muscular atrophy	2	.	.	.	.	.	2
Sensory changes	1	.	.	.	.	.	1
Other symptoms†	..	.	1	1	.	.	2
Treatment							
Infiltration therapy	15	3	3	1	1	.	23
No infiltration therapy	1[2]	3	.	3	.	4	11
Aspiration of calcareous material							
Successful	2	1	1	.	.	.	4
Unsuccessful	12	3	.	1	1	.	17
Not done	2[3]	2	2	3	.	4	13
Immediate reaction to infiltration therapy							
Exacerbation of pain	9	1	.	.	1	.	11
No exacerbation of pain	5	1	1	1	.	.	8
Unknown	1	1	2	.	.	.	4
X-ray findings after infiltration therapy							
Complete disappearance of deposit with clinical cure	11	1	1	.	.	.	13
Complete disappearance of deposit without clinical improvement	1	.	.	.	.	.	1
No changes in deposit with clinical improvement	1	.	1	1	.	.	3
No changes in deposit and no clinical improvement	1	.	.	.	1	.	2
Unknown	1	2	1	.	.	.	4
Follow-up							
1 yr.	5	.	.	1	.	.	6
2 yr.	6	1	.	.	.	.	7

TABLE II.—ANALYSIS OF 34 CASES OF TENDINITIS WITH CALCIFICATION AT VARIOUS LOCATIONS —Continued

Factor	Site of tendinitis						
	Shoulder	Elbow	Hip	Knee	Wrist	Foot	Total
Follow-up 3 yr.	1	.	.	.	.	.	1
None	4	5	3	3	1	4	20
Late results‡ Excellent	11	1	.	.	.	.	12
Good	1	.	.	1	.	.	2
Poor	..	.	.	.	.	.	..
Unknown	4[4]	5[5]	3[6]	3[7]	1[8]	4	20

*Acute—severe pain with disability; chronic—occasional pain without disability.
†Includes fullness and increased heat over affected area, Trendelenburg sign.
‡Excellent—disappearance of pain within a few days accompanied by gradual disappearance of the deposit and no recurrence of pain on follow-up; good—complete and permanent relief of symptoms without complete disappearance of the deposit; poor—persistence of pain and limitation of motion with or without diminution or complete disappearance of the deposit.
[1]One patient, who had tendinitis of the right shoulder to begin with, was found on follow-up to have occasional pain in the left shoulder also. The right (treated) shoulder was symptomless. X-ray showed absence of a deposit in the right shoulder, but there was a small deposit in the left supraspinatus tendon.
[2]This patient had a spontaneous recovery. Symptoms and deposit gradually disappeared with only physiotherapy.
[3]No attempt at aspiration was made in 1 case since there was no deposit, although the patient complained of occasional pain for the past 2 or 3 months during bowling. The second case was the patient who recovered spontaneously with only physiotherapy.
[4]The early result a few months after infiltration therapy is known in 2 cases, 1 of which had an excellent result and the other a poor result.
[5]The early result (a few months) is known in these 5 cases. Of 2 receiving infiltration therapy, 1 had a poor early result and the other an excellent immediate result. Of the 3 remaining cases, 1, treated by Dr. M. Burman, had a good early result in response to physiotherapy and rest; one, courtesy of Dr. H. Sonnenschein, had an excellent early result from open operation; and the third, courtesy of Dr. A. Kenin, had a good early result upon aspiration of the calcareous deposit.
[6]One had an excellent early result and 2 had a good early result. Of the latter, 1 was treated by Dr. M. Burman.
[7]One had a good early result when treated by rest and immobilization and 2 had a poor early result when similarly treated with physiotherapy.
[8]This case, courtesy of Dr. Leo Mayer, had a poor early result.
[9]This patient had calcification in the Achilles tendon. He is an example of a chronic, symptomless intratendinous calcification which was discovered during a general physical examination when a hard, rod-like, nontender mass was noted in the right Achilles tendon over the place of tenotomy in early childhood. The patient had had mild congenital right clubfoot which had been corrected by open lengthening of the Achilles tendon.
[10]This patient had tendinitis with calcification in the lumbrical and interosseal tendons of the left second toe, and had an excellent early result 3 months after open operation performed by another surgeon.

calcareous tendinitis because it seems to abort and shorten the acute stage and to prevent recurrences.

The amount of novocain solution and saline used seems to have no direct influence upon the results obtained, except that the solutions should be injected directly into the deposit. It also appears to be more rational to initiate the infiltration with a small amount of novocain followed by a larger amount of warm normal saline, since the latter is less toxic.

OBSERVATIONS

Tendinitis with calcification occurs far more frequently at the shoulder joint than in any other part of the body. This is borne out by Sandstroem's series of 329 cases of calcified tendinitis reported in 1938, in which the location of the lesion varied as follows: shoulder, 259 cases; hip, 48 cases; elbow, 6 cases; fingers, 6 cases; knee, 5 cases; toes, 3 cases; and wrist, 2 cases. In the author's series of cases the shoulder also was the most frequently involved.

This may be explained by the evolutionary changes of the shoulder joint and its anatomical and functional peculiarities. The scapulohumeral articulation in man has the greatest range of motion, as compared with any other joint. This extreme hypermobility is made possible by the great disproportion of the articular facets of the humeral head and the glenoid fossa. The articular surface of the head is four times greater than that of the glenoid fossa (Lanz and Wachsmuth, 1938). The angular value of the vertical arc in frontal plane formed by the glenoid fossa is 75 degrees, while that of the humeral head is 153 degrees (Steindler, 1935). Because of this difference in the articular surfaces, a very large part of the shoulder joint is represented by a joint capsule. According to Fick (1904), the intra-articular space is so great that it can accommodate a "second humeral head." The hypermobility of the arm is further augmented by the movable attachment of the scapula to the thorax.

In the horizontal posture of quadrupeds, both the front and hind legs are designed to bear the weight of the body, and the humeral head is pressed against the glenoid fossa in a manner similar to the femoral head bearing against the acetabulum. With the adaption of upright posture, the upper limb became suspended from the body. The weight of the arm itself tended to

separate the humeral head from the glenoid fossa. This was prevented by the joint capsule and the muscles, both of which were under tensile load in an upright position. Some of the muscles, especially the supraspinatus, are comparatively weak and inadequately adapted for the new mechanical requirements, because of the relatively recent adaption of upright posture. As stated by Codman, it became necessary for "the supraspinatus to lift the arm instead of swinging the foreleg." Lifting any weight, especially with the arm in frontal abduction, puts a tremendous tensile load on the capsule and muscles acting against great leverage.

As pointed out by Duplay, the shoulder joint is the only one in which, in addition to the intracapsular motion, there is a mobility between the capsule of the scapulohumeral articulation and the socket formed by the acromion and the coracoacromial ligament. The large subacromial bursa and the loose subdeltoid areolar tissue help to produce free gliding motion in this "second shoulder joint." Although most of the time the joint capsule and the periarticular soft structures are subjected to tension, occasionally there is reversion to the primitive mechanical condition. For instance, when something is pushed with the hand or when one falls forward on the outstretched hand, an upward thrust is produced, pressing the head of the humerus against the glenoid fossa and at the same time compressing the upper part of the joint capsule between the rigid socket of the "second shoulder joint" and the head of the humerus. This probably is the reason why the tendinous cuff of the shoulder joint, especially the uppermost supraspinatus tendon, is subjected to continuous mild traumatization or acute severe injury, resulting in degenerative changes with calcification or tendinous tears, respectively. It is doubtful that trauma may be immediately followed by formation of a calcareous deposit. Most probably it takes weeks, and possibly months, for calcification to take place. However, a latent deposit, whether of posttraumatic or other origin, may be activated by a recent injury to produce symptoms and disability in an apparently healthy individual.

In addition to trauma, there may be some metabolic predisposition of the individual toward calcification. This is evident from the fact that the deposit is rarely observed in young persons. The far greater frequency of involvement of the right shoulder noted in all reviewed papers indicates trauma as one of the etiological factors.

It is obvious that although tendinitis with calcification occurs most frequently at the shoulder it is by no means restricted to this location. The elbow, hip, knee, foot, and wrist have been involved in the author's series, as well as in cases reported in other publications. There is a close resemblance between the lesion at the shoulder and that at the hip due to homology of these two joints.

The infiltration therapy has been found to be successful in these different locations in acute cases. The author is fully aware of the possibility of the occurrence of spontaneous recovery with complete disappearance of the deposit in patients with acute calcareous tendinitis. Nevertheless, his observations have convinced him of a definite benefit from the infiltration therapy in acute cases. Relief of pain is often dramatic and, as a rule, is followed by disappearance of the deposit.

SUMMARY

1. Acute tendinitis with calcification most commonly occurs at the shoulder joint, although this lesion may be located in other parts of the body.

2. The infiltration therapy of acute tendinitis with calcification has given quite satisfactory results in the series of cases presented, with few exceptions. Treatment is accompanied by relief of pain after initial exacerbation of symptoms, and by gradual disappearance of the deposit.

3. In cases of "frozen shoulder" the infiltration treatment was found to be of no value, while in chronic cases with mild symptoms its effect is doubtful.

REFERENCES

1. Ayzac, C. Les calcifications des bourses séreuses périarticulaires. Thèse faculté de Médecine de Paris, 1926, No. 257.
2. Bergemann and Stieda, A. Münch. med. Wschr., 1908, 55: 2699–2702.
3. Brickner, W. M. J. Am. M. Ass., 1917, 69: 1237–1243.
4. Carnett, J. B. Surg. Gyn. Obst., 1925, 41: 404–421.
5. Codman, E. A. Boston M. & S. J., 1904, 150: 371–374.
6. Ibid., 1906, 154: 613–620.
7. Ibid., 1908, 159: 533–537.
8. Ibid., 1911, 165: 115–120.
9. Idem. The Shoulder. Boston: Thomas Todd Co., 1934.
10. Cowper. Quoted by Jarjavay, M. J. F., 1867.
11. Despates, H. Gaz. hebd., 1878, 15: 374–378.
12. Duplay, S. Arch. gén. méd., 1872, 2: 513–542.
13. Elmsie, R. C. Brit. J. Surg., 1932, 20: 190–196.
14. Ferguson, L. K. Surg. Gyn. Obst. (Internat. Abstr. Surg.), 1938, 64: 472–487.
15. Fick, R. Handbuch der Anatomie und Mechanik der Gelenke. Vol. 1. Jena: 1904, p. 171.
16. Flint, J. M. J. Am. M. Ass., 1913, 60: 1224–1225.
17. Haenisch, G. F. Fortsch. Röntgenstrahl., 1910, 15: 293–300.
18. Haggart, G. E., and Allen, H. A. Surg. Clin. N. America, 1935, 15: 1537–1560.

19. HALDEMAN, K. O., and SOTO-HALL, R. J. Am. M. Ass., 1935, 104: 2319–2324.
20. JARJAVAY, M. J. F. Gaz. hebd., 1867, 4: 325–327, 357–359, 387–391.
21. LANZ, T., VON, and WACHSMUTH, W. Praktische Anatomie. Vol. 1, part 4, p 96. Berlin: Julius Springer, 1938.
22. LERICHE, R., and JUNG, A. Rev. chir., Par., 1938, 76: 382–385.
23. MILGRAM, J. E. Personal communication.
24. MOSCHCOWITZ, E. Am. J. M. Sc., 1915, 150: 115–126.
25. PAINTER, C. F. Boston M. & S. J., 1907, 156: 345–349.
26. PATTERSON, R. L., JR., and DARRACH, W. J. Bone Surg., 1937, 19: 993–1002.
27. PATTERSON, R. L., JR., and PATTERSON, R. H. Am. J. Surg., 1940, 49: 403–408.
28. POURTIN (1902). Quoted by Ayzac, C., 1926.
29. PUTNAM, J. J. Boston M. & S. J., 1882, 107: 509–512, 536–539.
30. RICHARDS, T. K. N. England J. M., 1931, 205: 812–813.
31. ROGERS, M. Am. J. Surg., 1939, 43: 292–297.
32. SANDSTROEM, C. Am. J. Roentg., 1938, 40: 1–21.
33. SANDSTROEM, C., and WAHLGREN, F. Acta radiol., 1937, 18: 263–296.
34. SCHAER, H. Erg. Chir. Orthop., 1936, 29: 211–309.
35. SIEVERS, R. Deut. Zschr. Chir., 1914, 129: 583–653.
36. STEINDLER, A. Mechanics of Normal and Pathological Motion in Man. P. 290. Springfield, Illinois: Charles C. Thomas, 1935.
37. STIEDA, A. Arch. klin. Chir., 1908, 85: 910–924.
38. WEEKS, A., and DELPRAT, G. D. Internat. Clin., 1936, 3: 40–48.
39. WREDE, L. Arch. klin. Chir., 1912, 99: 259–279.

THE INHIBITORY EFFECT OF PROCAINE ON THE BACTERIOSTATIC ACTIVITY OF SULFATHIAZOLE

DANIEL CASTEN, M.D., JULIAN J. FRIED, M.D., and FRANCES A. HALLMAN, M S.,
New York, New York

THE increasing use of the sulfonamide drugs in the treatment of traumatic wounds has aroused considerable speculation as to the mechanism of their action and the factors which influence their activity. Since the report of Jensen and his co-workers on the treatment of compound fractures, surgeons have advocated the topical application of one of the sulfonamide drugs in a variety of infected or potentially infected wounds. That no ill effects have resulted from this use has been demonstrated by the work of Taffel and Harvey, Key and Frankel, and others, although Bricker and Graham noted some inhibition of wound healing following the local application of sulfanilamide crystals.

The action of the sulfonamides is bacteriostatic rather than bacteriocidal and the various drugs in this group exhibit a selective activity toward different pathogenic organisms. Furthermore, certain conditions may prevent completely or inhibit their bacteriostatic activity. Lockwood (5, 6, 7) has shown that small amounts of peptone and peptone-like substances in culture media inhibit the activity of sulfanilamide. Strauss and Finland detected a selective inhibition of sulfonamide drugs by media of blood, both human and horse serum, and liver infusion medium.

Spink and Jermsta have studied the *in vitro* effect of para-amino-benzoic acid on the bacteriostatic activity of sulfathiazole against Staphylococcus aureus and found that a definite inhibition of this activity occurred. Similar results were obtained by McCarty and by Keltch, Baker, Krahl, and Clowes, who worked with the various local anesthetics derived from para-amino-benzoic acid. The latter group observed that a definite antagonistic effect was exerted by these derivatives on the activity of sulfathiazole in solutions inoculated with Staphylococcus aureus and Bacillus coli.

The clinical applications of this experimental work are well worth considering. A study of the bacteriology of infected and traumatic wounds by Longacre revealed that the staphylococcus was an almost invariable inhabitant. The use of local anesthetics in the treatment of compound fractures and other traumatic and potentially infected wounds is widespread, and the anesthetic in most common use is probably procaine (B. diethylamino ethyl para-amino-benzoate), a derivative of para-amino-benzoic acid. If this compound exerts the same inhibitory effect on sulfathiazole *in vivo* that it does *in vitro* the present method of treatment may have to be revised.

A report of our experimental attempts to ascertain the occurrence of this phenomenon follows. Of course, it is realized that it is extremely difficult to produce experimentally a wound that is exactly analagous to the traumatic wound. In the latter, while the number of organisms may be less, the variety is greater and frequently, according to Meleney anaerobic bacteria may be present, or the various organisms present may have a symbiotic effect which pure cultures do not have. Furthermore, the nature of the traumatizing agent is usually quite dissimilar. However, since the Staphylococcus aureus is an almost constant inhabitant and is known definitely to be pathogenic, the experimental work was carried out on wounds inoculated with this organism.

METHODS OF STUDY

In these studies sulfathiazole was the only sulfonamide utilized. This drug is probably the one of choice for use in traumatic wounds because of its action on the almost constantly present staphylococcus and because of its relatively slow absorption. The infecting organism used was a strain of Staphylococcus aureus from a case of acute osteomyelitis (supplied by Dr. John E. Blair, bacteriologist, Hospital for Joint Diseases) which was known to produce a toxin. This was grown on brain-heart infusion agar for 24 hours and just before use each slant was washed off with 1.2 cubic centimeters of heart infusion broth. One slant was used for each wound. Preliminary experiments revealed that this method produced a local infection in every wound.

Rabbits weighing about 5 pounds (2.2 kilograms) were used in all experiments. Three days before operations the skin of the back was depi-

From the Laboratory Division and the Surgical Service of the Hospital for Joint Diseases.
Dr. Fried is now Captain, Medical Corps, A. U. S.

lated with barium sulfide. Anesthesia was induced by the intravenous administration of nembutal at the rate of 0.2 cubic centimeter per pound into the ear vein. The average dose per rabbit was 1 cubic centimeter. An incision about 1.5 to 2 inches long was made through the skin of the back, parallel to the spine and about 1 inch lateral and just caudad to the origin of the last rib. This was carried through the fascia, and the sacrospinalis muscle was exposed. By blunt dissection, the fibers of the muscle were separated and a small space was formed. Hemostats were applied to the muscle fibers surrounding the area and the muscle tissue was crushed to simulate as closely as possible the traumatic wound. Three series of experiments were carried out on these wounds. In series I the traumatized muscle wound was inoculated with the suspension of Staphylococcus aureus prepared as described previously. The wound was then closed with fine silk. In series II inoculation with the bacterial suspension was similarly performed and then 10 grains (0.65 gm.) of sulfathiazole powder was sprinkled into the wound. Previous experiments in which a smaller amount of sulfathiazole (0.35 gm. and 0.5 gm.) was used demonstrated that the smaller amounts of the drug were ineffective in inhibiting the infection. In series III the skin incision was made as above. The fascia was then infiltrated over an area of 1½ inches with 1 cubic centimeter of a solution of 2 per cent procaine and then incised. The muscle was infiltrated with 2 cubic centimeters of the same solution, and then the fibers were bluntly separated and crushed as in the previous experiments. The wounds were inoculated and the sulfathiazole was inserted as in the other groups. The wounds were likewise closed with fine silk.

All animals were observed for a period of at least 6 weeks following the operative procedures.

RESULTS

Series I. Twelve rabbits. All incisions became infected and definite abscess formation occurred within 2 weeks. The abscesses were thick walled and filled with a heavy purulent secretion. Cultures taken from the abscess cavities yielded Staphylococcus aureus.

Series II. Thirty-three rabbits. In 20 animals no gross evidence of infection was discernible during the period of observation (4 to 6 weeks). The wounds healed *per primam* and, except for a slightly increased amount of thickening, they differed in no way from healed noninfected wounds. The thickening was probably due to remnants of unabsorbed sulfathiazole powder.

TABLE I.—INCIDENCE OF INFECTIONS IN VARIOUS GROUPS

	Infection		No infection	
	Number	Per cent	Number	Per cent
Series I—wounds inoculated with Staphylococcus aureus	12	100	0	
Series II—wounds inoculated with Staphylococcus aureus and 0.67 gm. of sulfathiazole	13	39.3	20	60.6
Series III—wounds inoculated with Staphylococcus aureus and 0.67 gm. of sulfathiazole and infiltrated with 3 c.c. of 2 per cent procaine	26	100	0	

Several of the wounds were incised again after 2 or 3 weeks and cultures were taken. In all cases a staphylococcus was obtained corresponding to the infecting organism. This would lend support to the contention that the action of sulfathiazole is bacteriostatic rather than bacteriocidal. A delayed infection or an attenuated type of infection was observed in 8 rabbits. In these, the infection either developed very slowly as compared to the 2 week period in series I, or appeared in a much milder form. In the latter, no definite abscesses were observed but rather a diffuse infection with dehiscence of the wound and purulent drainage around the suture openings. In the animals with delayed infection a slowly developing induration and edema were observed for 7 to 14 days, and this was followed by breaking down of the wound and extrusion of small clumps of sulfathiazole powder and purulent material. Sections of the wounds revealed a true inflammatory process involving skin, muscle, and fascia. Finally, in 5 rabbits, definite abscesses developed within 2 weeks and were completely identical with those in series I.

Series III. Twenty-six rabbits. Definite abscesses developed in all animals. In several, the appearance was slightly delayed beyond the 2 week period observed in series I, but in no case was this delay beyond 3 weeks. The abscesses were fairly large and well localized. Occasionally the edges of the incisions separated but in a majority of the animals good healing of the skin and subcutaneous layers was observed.

ANALYSIS OF RESULTS

The studies heretofore described offer fairly definite experimental evidence that procaine, in the dilution and quantity used, will inhibit or entirely prevent the bacteriostatic activity of sulfathiazole in wounds infected, at the time of trauma, with a suspension of Staphylococcus au-

reus. Statistical analysis of these results demonstrates a significant difference between the percentage of infections in series II and series III. In the former, only 39.3 per cent of the wounds became infected, including those with slight or delayed infections, while in the latter 100 per cent developed abscesses. If we were to exclude those animals in series II in which the infection was minimal, the percentage difference would be even more striking. On the basis of these experiments, however, one cannot state that procaine would always be 100 per cent effective in inhibiting the activity of sulfathiazole, because, according to the laws of probability, one might still get infections in each of a group of 26 rabbits if procaine was only 84 per cent effective. We can be certain, however, that in groups similarly treated (series III) not less than 84 per cent of the animals would develop an infection. This figure (84 per cent) when compared to the 39 per cent of series II is still significantly different and, therefore, the results reported are definitely not due to chance alone. This statistical corroboration is essential in all work of this nature in order to eliminate the effect of chance variations, and to make certain that the numerical composition of each group is adequate for the conclusions drawn from the experimental results.

Sulfathiazole, therefore, may be said to prevent infection in experimentally infected wounds (Staphylococcus aureus) in approximately 60 per cent of the cases. The addition of 2 per cent procaine solution in amounts ordinarily used clinically will diminish this effectiveness considerably. In the present series it was 100 per cent effective in eliminating the bacteriostatic action of sulfathiazole, and from the standpoint of statistical evaluation, we may state that it will be at least 84 per cent effective in all similar groups.

The clinical application of these studies is evident. While procaine was the only derivative of para-amino-benzoic acid studied, the results of *in vitro* experiments would lead one to believe that other anesthetic agents derived from this chemical, would behave similarly *in vivo* (3, 14). Therefore in the treatment of infected or potentially infected wounds, it would seem advisable to forego the use of local anesthesia, or if this is impossible, to employ larger amounts of sulfathiazole and to use greater dilutions of the anesthetic agent.

SUMMARY AND CONCLUSIONS

1. The bacteriostatic action of sulfathiazole can be inhibited *in vitro* by many agents. Para-amino-benzoic acid and its derivatives are among the most potent of these inhibitors.

2. Many local anesthetic agents in common use are derived from para-amino-benzoic acid. Procaine (B. diethylamino ethyl para-amino-benzoate) is probably the local anesthetic used most frequently.

3. The experimental work reported herein has shown conclusively that procaine will inhibit the bacteriostatic activity of sulfathiazole in wounds inoculated at the time of trauma with a suspension of Staphylococcus aureus.

4. As a result of these studies we are of the opinion that the use of procaine for local anesthesia in the treatment of compound fractures and traumatic wounds is contraindicated when sulfathiazole is to be applied topically.

REFERENCES

1. Bricker, E., and Graham, E. A. J. Am. M. Ass. 1939, 112: 2593.
2. Jensen, N. K., Johnsrud, L. W., and Nelson, M. C. Surgery, 1939, 6: 1.
3. Keltch, A. K., Baker, L. A., Krahl, M.E., and Clowes, G. H. A. Proc. Soc. Exp. Biol., N. Y., 1941, 47: 533.
4. Key, J. A., and Frankel, C. J. Ann. Surg., 1941, 113: 284.
5. Lockwood, J. S. Surgery, 1941, 10: 493.
6. Idem. Ann. Surg., 1938, 108: 801.
7. Idem. Surg. Gyn. Obst., 1941, 72: 307.
8. Longacre, A. B. Surg. Clin. N. America, 1942, 22: 377.
9. McCarty, M. Proc. Soc. Exp. Biol., N. Y., 1941, 46: 133.
10. Meleney, F. L. Discussion of paper of Key and Frankel, loc. cit.
11. Spink, W. W., and Jermsta, J. Proc. Soc. Exp. Biol., N. Y., 1941, 47: 395.
12. Strauss, E., and Finland, M. Proc. Soc. Exp. Biol., N. Y., 1941, 47: 429.
13 Taffel, M., and Harvey, S. C. Proc. Soc. Exp. Biol., N. Y., 1941, 47: 202.
14. Woods, D. D. Brit. J. Exp. Path., 1940, 21: 74.

EVALUATION OF DYSMENORRHEA BY BASAL BODY TEMPERATURE

ROBERT A. LYON, M.D., San Francisco, California

PROLIFERATIVE as well as progestational premenstrual endometrium have been associated with dysmenorrhea by Hirst, Hamblen, and Cuyler. On the other hand, Wilson and Kurzrok observed secretory endometrium premenstrually in each instance of essential dysmenorrhea which they studied. They furthermore produced dysmenorrhea in an amenorrheic individual by means of progesterone. They concluded that only women with corpus luteum function can have dysmenorrhea. Sturgis and Albright (11) noted that dysmenorrhea did not occur in the absence of a secretory endometrium, thus tending to confirm the original observation by Wilson and Kurzrok. This association of ovulation and anovulation with dysmenorrhea seems to merit further examination.

It is the purpose of this presentation to investigate the contention, by means of the basal temperature approach, that ovulation is prerequisite to dysmenorrhea. Basal body temperatures of women, contrary to men, fluctuate during the month (6). Basal temperatures have been used by Rubenstein (7), A. Palmer (4), R. Palmer (5), Vollmann, and Zuck to indicate ovulation. Use is made of the sharp rise in basal temperature in the progestational phase of the ovulatory cycle. Such an alteration does not occur in the anovulatory cycle, so the temperature remains essentially unchanged throughout. However, the daily fluctuations may be relatively wide in range.

Vollmann observed that the duration of the premenstrual phase was relatively independent of the length of the menstrual cycle. On the other hand the duration of the postmenstrual phase varied directly with the cycle length. Rubenstein (8) plotted the zenith of cyclic basal temperatures at 5 to 10 days premenstrum, whereas the nadir averaged 15 days prior to menstruation.

Correlations between basal temperature and vaginal smear techniques were demonstrated by Rubenstein and Lindsley (9) during 5 menstrual cycles. Rubenstein concluded that the temperature cycle was as reliable an indicator of ovulation as the vaginal smear. There was established a +.93 correlation between the low point of the basal temperature curve and a smear typical of maximal estrone activity. This same author later (8) made use of the basal temperature for determination of ovarian function for which it was considered a better criterion than the vaginal smear.

Palmer and Devillers observed the effect of estrogen, progesterone, and testosterone on ovariectomized women in regard to basal temperature. Estrogens and testosterone produced a decrement in thermal level whereas progesterone caused an increase. Wertenberger, Collet, and Smith confirmed the fall in temperature during estrogen administration. A. Palmer (4) believes that the rises and falls are produced by activity of the ovarian hormones. By means of endometrial biopsy correlation, he concluded that the progestational phase of the normal ovarian cycle is relatively constant and averages 14 days in length regardless of the length of the cycle. He saw no exceptions to the correlation of basal temperature with the microscopic endometrial picture.

Barnes has suggested that temperature taken under basal conditions reflects the metabolic level. Progesterone utilization in physiologically effective amounts appears to raise the metabolism. This can be demonstrated upon progesterone administration to anovulatory women. It further appears that basal temperatures reflect the increase of metabolism occurring during progestation. Ovulation is, of course, a prerequisite to this state of affairs.

Sturgis (10) has recently defined essential dysmenorrhea as menstrual cramps associated with the presence of a secretory endometrium. He suggested the diagnostic differentiation between recurrent abdominal pain of other types and that of dysmenorrhea by means of inhibiting the secretory or progestational phase of the cycle, and claimed that the true dysmenorrhea can consistently and fully be prevented by estrogenic therapy. From these considerations it is clear that the basal temperature in women follows variation in the ovarian activity and reflects the progestational phase of ovulatory cycles. Therefore, it seems desirable to determine the basal temperature conditions in dysmenorrhea.

From the Department of Obstetrics and Gynecology, University of California Medical School.

This study was assisted by the Christine Breon Fund for Medical Investigation.

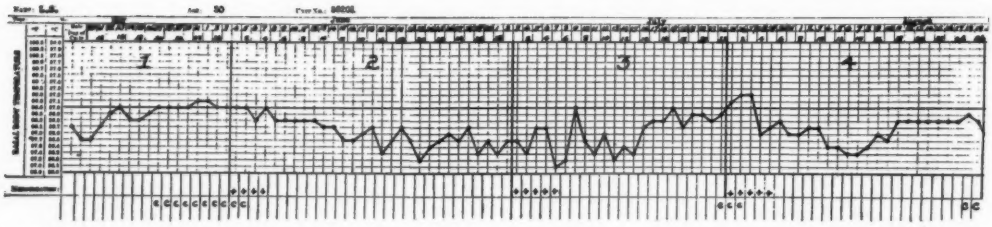


Fig. 1. Basal body temperature of successive cycles to include anovulation between two ovulatory cycles in an instance of primary dysmenorrhea. *C*, Symbolizes dysmenorrheic cramps. (1) Basal temperature increased during progestational phase of cycle suggesting ovulation. Cramps were present. (2) Aphasic temperature suggested anovulatory cycle. Cramps were absent. (3) Biphasic basal temperature suggested ovulation. Cramps were present (4) Ovulation again occurred, and cramps were again present.

OBSERVATIONS

Thirty dysmenorrheic women have been observed by means of basal temperature curves taken daily over a period of at least 3 months. One hundred and twenty-seven cycles have been studied. The patients ranged in age from 16 to 34 years, with an average age of 26 years.

Eighteen of the group had endometrial biopsy specimens taken late in the cycle. All of them had progestational endometria and all were associated with a premenstrual elevation in temperature. Furthermore, in 4 patients observed for more than 6 months each, sporadic anovulation as determined by basal temperatures was not accompanied by recurrent crampy pain.

Endometrial biopsy samples were obtained by the Novak curette between the 24th day of the cycle and the 1st day of the new cycle. They were also taken during the absence of ovulation. This resembled the picture seen in such conditions as hyperplasia of the endometrium or during lactation, and in simple agonadotropic anovulation. The endometrial pattern shows no progestation, and there is ordinarily no phase of temperature increment. In such instances the stroma retains a dense cellular appearance, and the uterine glands maintain their early proliferative pattern. In these instances of anovulation, there was no attendant pain of the dysmenorrheic type.

Endometrial samples from the dysmenorrheic patients here discussed showed reticulated loose stroma and wavy uterine glands representative of progestation in each patient examined. Although the incidence of anovulation in healthy young women is low, slightly less than 5 per cent as cited by Morton and Hayden, each instance of dysmenorrhea observed was accompanied by a temperature curve showing relatively high readings during the last half of the cycle.

Figure 1 presents the basal temperature record of one anovulatory painless 29 day cycle between two ovulatory cycles, both of which were accompanied by recurrent pain. The cycles represent the presence of late cyclic progestational metabolism rise in ovulatory cycles and its absence in the anovulatory cycle record.

CONCLUSION

It appears from this study that dysmenorrhea is associated with a temperature curve which has as its common factor the characteristic of late cyclic elevation associated with ovulation. When, for one reason or another, the cycle is anovulatory, there is no dysmenorrhea. No evidence is adduced in support of Hirst's contention that dysmenorrhea may occur in the presence of proliferative endometrium.

Anovulatory cycles as determined by either basal temperature records or endometrial biopsy were not associated with dysmenorrheic pain. Conversely, each episode of dysmenorrhea was associated with the characteristic temperature curve, typical of ovulation.

SUMMARY

One hundred and twenty-seven dysmenorrheic cycles have been followed in 30 women of age range 16 to 34 years. Progestational temperature rise occurred in the last half of the cycle in each instance of dysmenorrhea in each cycle in which dysmenorrhea occurs. Anovulation was not associated with dysmenorrhea. Basal temperatures appear to assist in the differentiation of essential dysmenorrhea from other rhythmical pains which may be associated with menstruation. This is confirmatory evidence by the basal temperature method of the regular precedence of ovulation in essential dysmenorrhea.

REFERENCES

1. Barnes, B. J. Am. M. Ass., 1942, 119: 1072.
2. Hirst, D. V., Hamblen, E. C., and Cuyler, W. K. J. Clin. Endocr., 1942, 2: 442.

3. MORTON, D. G., and HAYDEN, C. T. West. J. Surg., 1941, 49: 15.
4. PALMER, A. Surg. Gyn. Obst., 1942, 75: 768.
5. PALMER, R., and DEVILLERS, J. C. rend. Soc. biol., 1939, 130: 895.
6. RUBENSTEIN, B. B. Am. J. Physiol., 1937, 119: 635.
7. Idem. Endocrinology, 1940, 27: 843.
8. Ibid., 1938, 22: 41.
9. RUBENSTEIN, B. B., and LINDSLEY, D. B. Proc. Soc. Exp. Biol., N. Y., 1937, 35: 618.
10. STURGIS, S. H. N. England J. M., 1942, 226: 371.
11. STURGIS, S. H., and ALBRIGHT, F. Endocrinology, 1940, 26: 68.
12. VOLLMANN, U. Mschr. Geburtsh. Gyn., 1940, 111: 41, 121.
13. WERTENBERGER, G. E., COLLET, M. E., and SMITH, J. T. Am. J. Physiol., 1936, 116: 159.
14. WILSON, L., and KURZROK, R. Endocrinology, 1938, 23: 79.
15. ZUCK, T. T. Am. J. Obst., N. Y., 1938, 36: 998.

IMMEDIATE ACTIVE MOTION TREATMENT OF FRACTURES OF THE HEAD AND NECK OF THE RADIUS

JAMES A. MASON, Major, M.C., U.S.A., and NED M. SHUTKIN, Captain, M.C., U.S.A.,
Camp Joseph T. Robinson, Arkansas

A SURVEY of the literature concerning the treatment of fractures of the head and the neck of the radius indicates that there is great controversy as to whether conservative treatment with immobilization or radical treatment with the removal of the head of the radius is better. The very fact that such a controversy exists is indicative that either treatment leaves much to be desired as far as the restoration of normal function is concerned. This, too, is clearly brought out by the reports of the results obtained in various series of cases. With this in mind, this report presents a series of unselected cases of fractures of the head and neck of the radius treated by a third method, that is, the immediate use of active motion and local heat with no immobilization other than the use of a simple arm sling. Perusal of the literature reveals only two other instances in which early active motion is advocated. One instance is that of a report by Colp who advocates immediate resection of the head in all cases, irrespective of the amount of displacement with immediate active motion after operation. The other is that of a recent report by Neuwirth dealing with 6 cases of varying types of elbow fracture which were treated successfully with immediate active motion.

ESSENTIAL ANATOMY

In discussing the rationale of this treatment, it is necessary to consider certain anatomical features of the elbow joint. The elbow joint is unique in the body, being a bicondylar joint with the humerus articulating with the ulna and the radius, and also with the close approximation and relation between the proximal ends of the radius and ulna. The two condylar joints do not have the same axis, nor do they move through the same arc. Consequently, in order for a normal range of flexion and extension to be present, these 2 joints must be perfectly synchronized. Therefore, any anatomical variation disturbing the axis or arc of either of these joints will produce some degree of mechanical block. Cohn states that "any change in the axis of an articular surface is bound to produce a partial or complete ankylosis of the joint." It follows, therefore, that reduction of the fragments of a fractured elbow may eliminate any obvious deformity but still not restore the state of synchronization of the two condylar joints, with appreciable impairment of function resulting. Furthermore, x-ray evidence has not proved an accurate guide as to whether the position of the fragments is normal anatomically, and, therefore, fixation until calcification has occurred will succeed in nothing except to insure that synchronization is lost and bony blocking of the joint motion will result. The massage, active and passive motion, and other routine physical measures employed for the restoration of function will not only be unavailing but may even do further damage in that injudicious attempts to increase the range of motion by these methods may compress the articular cartilage, initiate a hypertrophic arthritis, or produce a hematoma that may rapidly ossify.

The head of the radius has two important functions: one is its articulation with the ulna to form

From the Orthopedic Section, Surgical Service, Station Hospital, Camp Joseph T. Robinson, Arkansas.

the proximal radioulnar joint through which rotation of the forearm is executed, and the second is its rôle in maintaining lateral stability of the elbow joint. The close relationship of the radial head to the ulna is an important consideration since exuberant callus formation may ankylose the proximal radioulnar joint, thereby impairing rotation of the forearm.

CONVENTIONAL TREATMENT

After the presence of a fracture is established the question of treatment arises. In general, conservative treatment is used in fractures with little or no displacement, and resection of the uncontrollable capital fragment is employed in fractures with gross displacement. That neither method is particularly satisfactory is obvious from the reports and opinions of various authors. Eliason and North conclude that "in none of these cases should too optimistic a prognosis be given, for traumatic arthritis with painful restrictive rotation may follow an apparently minor injury, with or without displacement and regardless of treatment."

Bohrer, in a report on 20 cases, 12 of which were treated conservatively and 8 by resection of the head of the radius, concludes that both methods result in appreciable loss of function, especially due to synostosis of the radius and ulna, producing loss of rotation. Callus formation may produce this after operation, as well as with conservative treatment. Synostosis due to exuberant callus occurred in 50 per cent of the 8 patients operated upon in his series. With the 12 patients treated conservatively, the results were consistent with the amount of displacement.

Schwartz and Young report a series of cases treated conservatively in which all showed some disability, although in the cases with little or no displacement, functional results were adequate. These authors are opposed to resection of the head of the radius, stating that this structure is essential for the stability of the elbow joint, and that its removal produces relative lateral instability. Cubbins, Callahan, and Scuderi concur with this observation, as also does Magnuson.

King reports a series of 13 cases, all treated with early resection of the head. He considered 1 result excellent; 5, good; 4, fair; and 3, poor. These figures indicate that there was some disability in all but 1 of the cases, and that in over 50 per cent of the cases there was appreciable disability. The author states that "in too many instances of resection, it is taken for granted that the procedure is harmless and free from undesirable sequelae."

Hein analyzes the end-results of 52 cases, with special reference to disability. Fractures with little or no displacement were treated conservatively; those with great displacement were treated surgically. In group 1, consisting of 25 cases with no displacement and treated conservatively, there were 21 normal results. In group 2, consisting of 11 cases with displacement and treated conservatively, 8 had limited extension, 5 had limited flexion, and 4 were chronically painful. In group 3, consisting of 11 cases with displacement and treated with early resection, good functional results were obtained generally, but some disability ensued in all cases. In group 4, consisting of 5 cases with displacement and treated with late resection, all had marked decrease in flexion and extension, 4 had marked limitation of both pronation and supination, 1 had complete loss of rotation, and 3 were chronically painful. The average time lost was as follows: group 1, 4.66 weeks of disability; group 2, 10 weeks; group 3, 8.5 weeks; and group 4, 23 weeks.

RATIONALE OF ACTIVE MOTION TREATMENT

The review given of series of cases reported certainly does not indicate an especially satisfactory result in the conventional conservative treatment. Eliason (5) states "function is to be striven for at the expense of anatomical alignment." He further states in another paper (6) that "after an injury to the elbow the restoration of normal function requires the preservation of the contours and relationships of its several articulating surfaces.' The conventionally accepted premise of the conservative treatment of these fractures has, therefore, been based on an attempt to restore anatomically the articular surfaces to as nearly normal as possible, and then to use some method of fixation until the fragments are sufficiently callused to warrant motion without too much possibility of further displacement. However, it is possible that a different premise is more acceptable, at least in the cases under discussion at this time, namely, fractures of the head and neck of the radius, because we are dealing with small uncontrollable fragments, the even minute displacement of which may destroy the synchronization of the multiple articular surfaces of the elbow. As a corollary, there is a logical rationale for the nonfixation treatment in fractures of the head of the radius. The fundamental fact to keep in mind is that these fragments are small and uncontrollable. By beginning active motion of the elbow early, before the fragments have become fixed, they will be moved across the fixed, uninjured articular surfaces of the humerus, and will thus attain the best functional position in relation to the various joint surfaces.

Under this management, no fixation of the elbow is used other than a simple arm sling holding the elbow at a right angle, this being as nearly a neutral position for the elbow as possible. Continuous hot wet packs are used for as long as is necessary to treat the soft tissue injury and to overcome muscle spasm. Morning and evening the elbow is guided gently by the physician through its range of active motion, extension and flexion being performed with the forearm in supination and an attempt being made to have the patient balance the range of flexion with equal range of motion in extension. Then the forearm is actively moved through its range of supination and pronation. It is to be emphasized that the patient himself is performing the motion, merely supported and guided by the physician, and that at no time is any forceful passive motion used under this management of the early injury. If this procedure is carried out carefully, it is rarely necessary to use any degree of passive force, and that only after the third week of treatment and in the exceptionally unco-operative patient, and then only with great care and the exertion of minimum force.

Additional advantages gained by this method of treatment are the improvement of circulation to the injured area which minimizes the amount of soft tissue scarring and the reduction of degree of scar tissue contracture. Also close observation of the injured member is possible from the outset, permitting early recognition of any complications, such as nerve damage, or such an unfortunate sequela as von Volkmann's ischemic contracture, and would permit early treatment being instituted in such cases.

CLASSIFICATION OF CASES

Between May 18, 1941, and August 13, 1942, there were admitted to the Station Hospital, Camp Joseph T. Robinson, Arkansas, 25 patients with fracture of the head of the radius. Seven of these patients (group 1) were admitted prior to April 1, 1942, and were treated by the conventional type of management. Eighteen were admitted after April 1, 1942 (group 2) and have all received the nonfixation, local heat, and active motion type of management.

In attempting to evaluate the results, the following classification was used:

Class A. Linear, transverse fractures of the head, without displacement, and transverse and impacted fractures of the neck without displacement. This group would, under the conventional management, receive fixation for varying periods, from 10 to 30 days, followed by physiotherapy.

Class B. Comminuted fractures of the head without displacement or with minimal displacement. This group would conventionally be treated conservatively with longer periods of fixation, with the possibility of subsequent excision of the head of the radius if functional results should prove unsatisfactory. Into class B were placed also fractures of the class A type that were complicated by complete dislocation of the elbow at the time of injury, as it was found that this group was slower in regaining function because of the extensive soft tissue damage.

Class C. Comminuted fractures with marked displacement. These are generally operated upon early with excision of the head of the radius.

Class D. Transverse fractures of the neck with displacement of the head, which is often found rotated 90 degrees more or less from its normal longitudinal axis. These patients also require early operation with either replacement or excision of the head as the case may require.

In this series there were no patients coming under class D. There was only 1 patient that fell into class C, and he was transferred to an army general hospital where operation was performed; however, an opportunity to follow and examine him subsequently permits the inclusion of this patient in the series. Under class B there were 3 in the conventionally managed group and 7 in the recent group, making a total of 10 patients. In class A there were 3 in the first group, and 11 in the subsequent group, making a total of 14 patients. It is, therefore, obvious that any conclusion which may be drawn from this series can be applied only to the types of fractures of the head and neck of the radius classified under class A and class B.

No attempt will be made to discuss the incidence, etiology, or to further elaborate upon the pathology in these cases, as the primary object of this discussion is to compare the results obtained under the two types of management outlined above.

HOSPITALIZATION PERIOD

In considering the series from the standpoint of period of hospitalization, one must remember that a distinct difference exists between the period of hospitalization in an army hospital and that in a civilian hospital. The former is longer because the patient remains in the hospital until he is capable of performing full duty, whereas the same patient in civilian life would probably be hospitalized only 10 days or 2 weeks and then be returned home for further outpatient care and convalescence. One patient presents an example

TABLE I.—HOSPITALIZATION

Group 1

Class A		Class B	
Case No.	No. of days	Case No.	No. of days
4	37	1	85
5	44	2	118
6	198	3	118+
Average	93	Average	107+

Group 2

Class A		Class B	
Case No.	No. of days	Case No.	No. of days
9	42	8	49
10	22	12	52
11	33	15	58
13	47	18	56
14	9	19	51
16	48	21	59
17	26	23	49
20	51	Average	53
22	42		
24	42		
25	33		
Average	36		

TABLE II.—FUNCTIONAL RESULTS

Group 1

Class A			Class B		
Case No.	End-result per cent	Days	Case No.	End-result per cent	Days
4	100	37	1	80	85
5	100	44	2	90	118
6	70	198	3	50	118+
Average	90	93	Average	75.5	107+

Group 2

Class A			Class B		
Case No.	End-result per cent	Days	Case No.	End-result per cent	Days
9	100	42	8	100	49
10	100	22	12	100	42
11	100	17	15	100	42
13	100	42	18	100	56
14	100	28	19	100	42
16	100	35	21	95	59
17	100	21	23	95	49
20	100	49	Average	98.6	48
22	100	14			
24	100	28			
25	100	19			
Average	100	29			

of how these patients might be handled under civilian management. He was an officer who was discharged after 9 days of hospitalization since his duties did not necessarily involve strenuous use of the arm. Incidentally, in civilian practice many of these patients would be treated, no doubt, in the home without any hospitalization.

Both groups 1 and 2 were treated in an army hospital, and, therefore, the period of hospitalization includes the period of convalescence. A comparison of the periods of hospitalization in both groups, therefore, should be an accurate gauge of the method of treatment (Table I). In group 1 (conventional treatment group), in class A, the period of hospitalization varied from 37 to 198 days, with an average of 93 days. In group 2 (active motion management), the hospitalization in class A ranged from 9 days to 51 days, with an average of 36 days. In group 1, class B, the hospitalization varied from 85 days to over 118 days, in the latter instance the patient received even further hospitalization in an army general hospital for an unknown duration and with unknown end-results. The average time in this series was over 107 days. In group 2, class B, the period of hospitalization varied very little and averaged 53 days. The 1 patient in class C had a total hospitalization period of 87 days. These figures indicate a much shorter period of convalescence in general for the second (active motion) method of management.

PERIOD OF DISABILITY

However, in contrasting the 2 methods of management, of even more significance than the total period of hospitalization is the period of time required to attain the end-result functionally (Table II). In this respect, in group 1 the end-result functionally was equivalent to the total period of hospitalization as given heretofore. But in group 2, class A, function was attained in from 17 days to 42 days with the lone exception of 1 hysterical, uncooperative individual who required 49 days. The average time was 29 days. In group 2, class B, there was less variation, and function was attained in an average time of 48 days. This average also is a distinct improvement over that for patients in the first group.

FUNCTIONAL RESULTS

An attempt has been made to estimate the end-result in percentage of function. Where no limitation in range of motion was present, or only 5 degrees' limitation by actual measurement, and with normal, painless muscle power, function was listed as 100 per cent. When there was good function but even 10 degrees' limitation of range of motion by measurement, function was estimated at only 95 per cent, although actually no disability was present. Other cases were definitely graded lower because of obvious disabilities being present.

From this standpoint, in group 1, class A, there were 2 patients with 100 per cent function, and 1 patient with about 70 per cent function. In group 2, class A, all 11 patients had 100 per cent functional end-results. In group 1, class B, the 3 patients were functionally rated 80 per cent, 90 per cent, and 50 per cent under the conventional method of management. But in group 2, class B, 5 of the 7 patients attained 100 per cent function, and 2 patients were rated 95 per cent, although no actual disability was present. These last 2 cases were complicated by complete posterior dislocation of the elbow at time of injury and are, therefore, directly comparable to the relatively poor results obtained in similar cases in group 1, class B. The lone patient in group 1, class C, was rated 60 per cent functional end-result.

CALCIFICATION IN SOFT TISSUES

Some interesting sidelights on particular patients in this series were discovered. Of the 7 in group 1, 5 showed evidences of calcification in the soft tissues about the elbow. One of these had marked calcification apparently in an area of hematoma following the fracture-dislocation of the elbow. Of the 18 in group 2, only 1 showed any tendency to calcification in the soft tissues, and this to a much lesser extent, although this patient was also a fracture-dislocation of the elbow with marked swelling of the joint after injury. This difference was attributed to the improved circulation from the use of continuous hot packs until the soft tissue reaction had subsided.

DISPLACEMENT OF FRAGMENTS

In the cases in group 1 the follow-up x-ray films showed essentially no change in the position of the capital fragments after reduction; however, in group 2 there were 5 patients whose checkup films showed slight to rather definite further displacement of the small, uncontrollable fragments of the head of the radius, and yet these patients were all progressing in function under the active motion management to a very satisfactory (95 to 100 per cent) functional end-result. One interesting patient incurred a comminuted fracture of the head of the radius with a longitudinal splitting and impaction of the neck of the radius with moderate displacement of fragments, but under the active motion management attained 100 per cent function in 6 weeks, and checkup films showed, curiously enough, a more normal appearance with less displacement of fragments, only 2 small fragments being visibly displaced as compared with 4 fragments on the original film. These findings are corroborative of the premise presented above, namely, that anatomical reposition of the displaced fragments is not necessary to regain synchronization of the multiple joint surfaces, but rather that early active motion permits these fragments to assume the optimum functional position in relation to the fixed, uninjured articular surfaces.

FOLLOW-UP

In postulating any conclusions from this series it must be admitted that the follow-up period is inadequate. With less than 1 year's observation of results it is not possible to exclude subsequent development of posttraumatic arthritis in the cases under the active motion regimen. Unfortunately, with the rapid transfer of army personnel at the present time, supplemental information regarding this possibility will probably be unobtainable. However, it is our opinion that this series presents some valuable points for consideration. The following case abstracts exemplify some of the results analyzed.

ABSTRACTS OF CASE REPORTS

Group 1

CASE 3. A 30 year old soldier was admitted to the Station Hospital on August 27, 1941, with the history of having sustained a fall the previous day during 2nd Army maneuvers, landing on right hand, with the elbow bent to an angle of 90 degrees and the forearm pronated. A laceration of the right thumb was sutured at a civilian hospital, and the patient was then transported to Camp Robinson. An x-ray picture taken on admission revealed a complete posterior dislocation of the right elbow, and a chip fracture of the head of the radius. The dislocation was reduced under gas-oxygen-ether anesthesia, and the arm was immobilized at a right angle with a plaster splint. The splint was removed at the end of 3 weeks, and motion was resumed. Appreciable limitation of flexion, extension, and rotation persisted despite all efforts of physiotherapy. On October 9, 1941, under intravenous pentothal sodium anesthesia, the right elbow was manipulated, with temporary increase in the range of motion which lasted only a few days. An x-ray film taken on December 1, 1941, revealed a large calcifying hematoma in the soft tissue about the elbow joint. On December 23, 1941, after 118 days of treatment, the patient was transferred to an army general

hospital. At time of transfer, he had an estimated 50 per cent function of the right elbow.

CASE 6. A 24 year old soldier was admitted to the Station Hospital on October 26, 1941, with an injured left elbow sustained that day when he fell, landing on the elbow. X-ray examination revealed a fracture of the head of the radius, involving the articular surface. Closed reduction and the application of a long arm plaster cast was performed the following day. Motion was resumed after 3 weeks, with appreciable limitation of motion persisting. The elbow was manipulated under general anesthesia on January 23, 1942, with some improvement. Continued physiotherapy was unavailing, and the patient was transferred to an army general hospital on February 23, 1942, after 198 days of hospitalization, with a function of 70 per cent in the left elbow. X-ray examination revealed some calcification of the soft tissues and a mild traumatic arthritis.

Group 2

CASE 14. An officer, aged 35 years, was admitted to the hospital on June 20, 1942, with a history of having fallen the previous day while running an obstacle course, landing on the point of his left elbow. Examination of the left elbow revealed moderate swelling and limitation of all movements, with tenderness over the head of the radius. Stereoscopic x-ray films of the elbow revealed a simple, complete, linear fracture through the anteromedial aspect of the head of the radius, involving the articular surface, with slight downward displacement of the smaller fragment. The closed treatment, consisting of immediate active motion, hot packs, and an arm sling as the only means of immobilization, was instituted. Rapid improvement of function followed. The patient, whose duties did not require strenuous use of his arm, was discharged on the 9th hospital day with instructions to continue wearing the sling and to be followed as an outpatient. The function of the elbow at the time of discharge was as follows: flexion to 40 degrees, extension to 155 degrees, with 100 per cent supination and pronation. There was no pain, swelling, or instability. Follow-up of the patient revealed complete return of function in 28 days. An x-ray film taken 4 weeks post-trauma showed an indistinct fracture line and the same deformity as was noted on the initial films. No excess callus was demonstrable.

CASE 15. A soldier, aged 30 years, was admitted to the hospital on June 23, 1942, with an injured left elbow sustained that day when he fell backward as he swung off a horizontal bar, landing on his left elbow. Examination of the elbow revealed appreciable pain and swelling, with great limitation of motion and point-tenderness over the head of the radius. X-ray examination revealed a simple, complete, comminuted fracture through the anteromedial aspect of the head of the radius, involving the articular surface and extending down into the shaft of the bone, splitting it for a distance of 3 centimeters. The immediate active motion treatment was instituted. In 14 days flexion and extension were about normal, but there was slight limitation of both supination and pronation with pain on the extremes of these motions. Muscle power was normal, and there was no instability. The full range of supination and pronation was gradually obtained, and in 6 weeks there was full return of function without any pain, weakness, or instability. X-ray films showed the same position as on the initial films. The fracture line was less distinct, and no excess callus formation was noted.

CASE 22. A 23 year old soldier was admitted to the hospital on July 27, 1942, with an injured left elbow sustained the previous day when he fell, while running an obstacle course, and landed on his left elbow. Examination revealed pain, swelling, limitation of motion, and point of tenderness over the head of the radius. Stereoscopic x-ray films revealed an incomplete fracture through the lateral rim of the head of the radius, involving the articular surface, with slight distal displacement of the smaller fragment. The active motion treatment was instituted with rapid return of function. Within 1 week, extension, pronation, and supination were normal, and flexion was slightly limited to an angle of 40 degrees. There was complete return of function at the end of the 2d week when the patient was discharged from the hospital. At this time an x-ray picture showed the fracture line to be less distinct. No callus or change in position was noted.

CASE 23. A 27 year old soldier was admitted to the hospital on July 28, 1942, with a severely injured left elbow sustained that day when the patient fell while running an obstacle course, landing on his left palm with the elbow bent to a right angle and the forearm in midpronation. Clinical examination revealed an obvious complete posterior dislocation of the radius and ulna on the humerus. This was corroborated by x-ray examination. The initial film failed to reveal any factures of the radial head. There was marked swelling and ecchymosis about the elbow. The dislocation was reduced by manual traction under pentothal sodium anesthesia. The arm was immobilized with only a sling; hot packs were applied, and active motion instituted. Stereoscopic views of the elbow taken 10 days later revealed two small chip fractures off the lateral aspect of the head of the radius. In 3 weeks there was moderate return of function with flexion to a 60 degree angle and extension to 160 degrees. Pronation and supination were 85 per cent and 100 per cent, respectively. Muscle power was good. Evidence of considerable ecchymosis persisted. At the end of 5 weeks, flexion was 45 degrees, extension was 180 degrees, and both pronation and supination were 100 per cent. There was no pain or instability. There was no further return of flexion, and the patient was discharged at the end of 7 weeks. X-ray examination at the time of discharge revealed no change in the appearance of the fractured head of the radius. No callus was noted, but there was some calcification in the soft tissues lateral and inferior to the lateral and medial epicondyles.

SUMMARY AND CONCLUSIONS

1. A survey of the literature reveals that the treatment of fractures of the head of the radius is a controversial matter and with generally not too satisfactory results.

2. A series of 25 cases of fracture of head of the radius is presented.

3. One group of 7 cases was treated under conventional management with generally unsatisfactory results.

4. A second group of 18 cases was treated without fixation, with local heat, and early active motion. The results, as measured by comparable periods of hospitalization, absence of complications, and estimated percentage of function (95 to 100 per cent), were a distinct improvement.

5. The classification used in this discussion limits conclusions to be drawn only as regards linear, transverse, or comminuted fractures of the head and neck of the radius with no displacement or with only mild displacement of the fragments.

6. Inadequate period of follow-up precludes the elimination of posttraumatic arthritis as a possible late complication under this management, although no patients to date have manifested any symptoms.

7. A rationale for the active motion and local heat management is advanced chiefly on the following basis:

a. The elbow is anatomically a multiple joint with synchronization of joint surfaces being essential to function.

b. The fractured fragments of the head of the radius are characteristically small and uncontrollable.

c. Early active motion permits these fragments to be moved across the fixed uninjured articular surfaces of the elbow joint to attain the position where maximum function is possible.

d. The use of local heat in the form of hot packs permits early elimination of soft tissue reaction and lessens the tendency, frequently seen under conventional management, of calcification of soft tissues about the injured joint.

REFERENCES

1. BOHRER, J. V. Ann. Surg., 1932, 97: 204–208.
2. COHN, ISADORE. Am. J. Surg., 1942, 55: 210–227.
3. COLP, RALPH. Internat. Clin., 1930, 2: 208–212.
4. CUBBINS, W. R., CALLAHAN, J. J., SCUDERI, C. S. Am. J. Surg., 1938, 42: 627.
5. ELIASON, E. L., and JOHNSON, J. In Christopher's: A Textbook of Surgery. P. 566. Philadelphia and London: W. B. Saunders Co., 1936.
6. ELIASON, E. L., and NORTH, J. P. Am. J. Surg., 1939, 44: 89–99.
7. HEIN, B. J. Indus. M., 1937, 6: 529–532.
8. KEY, J. A. J. Am. M. Ass., 1931, 96: 101–104.
9. KEY, J. A., and CONWELL, H. E. The Management of Fractures, Dislocations, and Sprains. 2d ed., Chapt. 18. St. Louis: C. V. Mosby Co., 1937.
10. KING, B. B. J. Bone Surg., 1939, 21: 839–857.
11. MAGNUSON, P. B. Fractures, 2d ed. Philadelphia, Montreal, London: J. B. Lippincott Co., 1936.
12. NEUWIRTH, A. A. J. Am. M. Ass., 1942, 118: 971.
13. SCHWARTZ, R. P., and YOUNG, F. Surg., Gyn. Obst., 1933, 57: 528–537.
14. THORNDIKE, A., JR., and DIMMLER, C. L. N. England M. J., 1941, 225: 475–480.
15. WILSON, PHILIP D. Management of Fractures and Dislocations. Chapter VI. Philadelphia: J. B. Lippincott Co., 1938.
16. Idem. Surg. Gyn. Obst., 1933, 56: 335.

THE RATE AND NATURE OF EPITHELIZATION IN WOUNDS WITH LOSS OF SUBSTANCE

EDWARD L. HOWES, M.D., F.A.C.S., New York, New York

IN the previous attempts made to calculate the rate of epithelization, microscopic cross sections were cut from healing wounds with loss of substance and the length of extension of new epithelium from the old was calculated for the number of days of existence of the wound. This method was used by Akaiwa in 1919, in Loeb's laboratory, and has recently been employed again in the study of wounds by Dann, Glucksmann and Tansley, and by Olson, Slider, Clark and MacDonald. In the last 2 studies no allowances were made for the presence of a latent period when epithelization does not occur. In Akaiwa's work, more attention was given to the number of mitotic figures which were present than to the rate of epithelization.

The nearest approach to a satisfactory method of measuring the rate of epithelization without recourse to biopsy was described by Carrel and Hartmann. They measured and plotted the change in the size of the original outline of the wound and in the size of the unepithelized area during healing. By subtracting the size of the unepithelized area from the size of the wound as contraction occurred, the amount of epithelization could have been determined. Actually, however, these investigators never did calculate the rate of epithelization.

Previous methods had the objections that (1) the size of the wound could be decreased by contraction and (2) there was no satisfactory measure of the progress of epithelization. This paper presents a method free from these objections.

METHOD

In this investigation, color photography was used to record the progress of epithelization.

In order to eliminate contracture from influencing the results, the outward growth of epithelium from an island of skin was measured. Any change in the size of this island caused by contraction could be readily observed. Further, the wounds were placed on the ears of rabbits where contraction is minimal because of the peculiar anatomy. Here the skin rests only on a small amount of connective tissue surmounting cartilage.

A defect approximately 2 centimeters square was cut in the skin on the outside of the rabbit's ear, leaving uninjured the blood supply in the base of the defect and the small square island of skin of approximately 2 to 3 square millimeters at its center. To prevent wrinkling and deformation, a rubber form was affixed within the ear by means of adhesive plaster. The desired dressing was placed over the wound and a hood[1] of muslin or oiled skin, tailored to fit and opening by means of snaps, was then sutured to the base of the ear. These hoods were sewed together with 2 or 3 stitches on their inner margins causing them to hang like a cape over the back of the animal instead of weighing each ear down separately. With the protection afforded by these hoods, bandages were rarely lost, and either wet, dry, or ointment dressings could be employed within them.

To photograph the island, the rabbit was placed in a box which held its head securely in an upright position. A small movable table was placed on top of this box behind the ears of the animal and the ear fastened to it in a relatively flat position by inserting pins through the rubber form. A precision photographic enlarger equipped with a 1.5 lens and a 35 millimeter camera and slide viewing back was used to make the kodachromes (Fig. 1). A cleared area in the ground glass of the slide viewing back allowed accurate focusing by means of a magnifying glass. Two small spotlights were thrown on the wound from opposite sides at 45 degree angles, thereby reducing the number of highlights. This illumination was controlled by a high-low switch to minimize drying while a correct focus was being obtained. The wound was also kept moist with saline solution.

In order to obtain the same relative magnification for each photograph, a standard bellow length was employed. Focus was obtained by raising and lowering the object under the camera by means of an adjustable table. A sterile steel rod, measuring 5.0 millimeters in length was photographed on each wound. The degree of enlargement of this rod was checked on the viewing glass before the picture was taken. A standard enlargement of it

From the Laboratories of Surgical Pathology and the Department of Cancer Research, College of Physicians and Surgeons, Columbia University, New York.

[1]Designed by Miss Daisy Mapes, nurse in charge of the animal operating room.

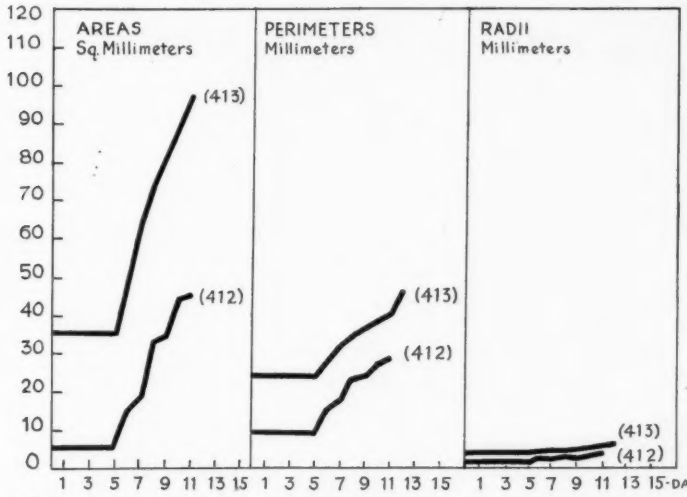


Chart 1. Comparison of increase of large (413) and small (412) islands of skin.

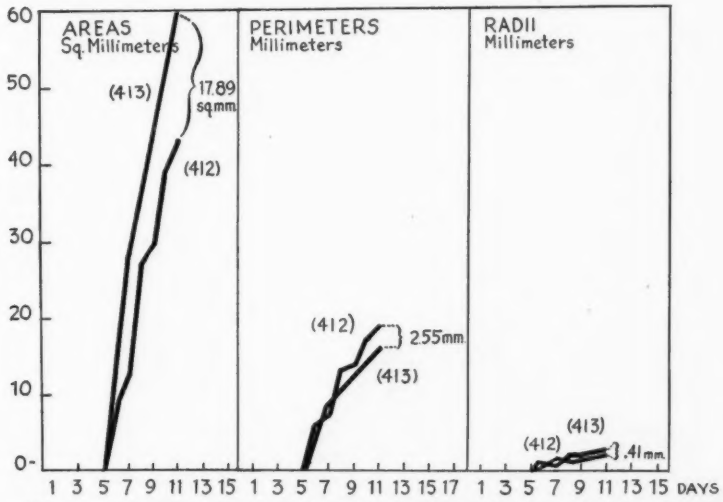


Chart. 2. Comparison of growth of large (413) and small (412) islands of skin plotted by daily increments.

was employed to measure changes in size of the island during healing after the film was developed.

Growth of the epithelizing island was measured by projecting the kodachrome from the enlarger onto a sheet of bond paper. The steel rod was magnified to 50 millimeters, which is ten times its actual size. The outline of the island was then traced, cut out, and weighed. The area of this tracing was calculated by the gravimetric method of Douglas (4)—the weight of the tracing being divided by the weight of a known unit of area of the paper. Allowance was made for the degree of enlargement.

Microscopic sections were cut from these islands at various intervals to study the progress of epithelization.

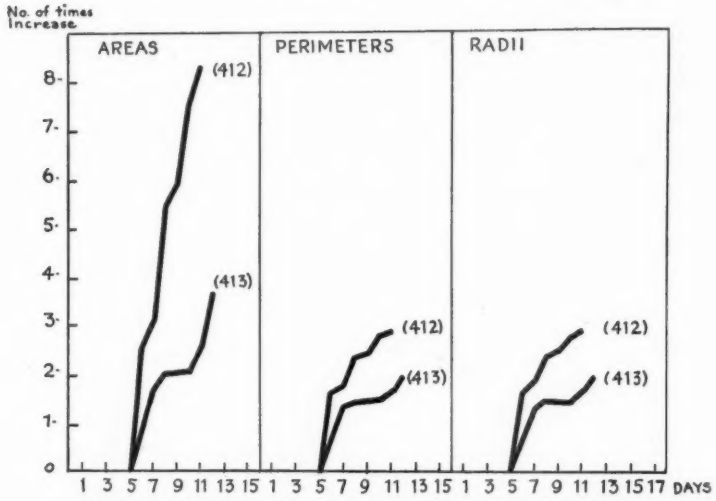


Chart 3. Comparison of large (413) and small (412) islands of skin plotted as number of times increase over original.

THE LATENT PERIOD

There was a latent period of 4 or 5 days' duration before epithelization started. Extremes of 3 to 6 days were observed without evidence of infection to account for the longer periods. As soon as epithelization began, the edges of the square flattened and blended with the surrounding granulations. The sharp cut edge disappeared. The center island became round, and further growth enlarged the circle.

Repeated daily dressings prolonged the onset of epithelization. A latent period of 6 days was obtained, for example, when a dressing was changed every day beginning on the 2d day, while if this same type of dressing was left undisturbed, epithelization was either just beginning when it was removed on the 4th day or the process started on the following day.

MEASURING THE RATE OF EPITHELIZATION

From the start of the experiments it was obvious that some decision had to be reached as to the proper method of expressing the rate of epithelization. Should area be employed or the number of times the area increased in size or the change in the length of perimeter or the rate of linear extension? To determine the proper measurement to employ, epithelization was compared about a small and large island of skin by three different measurements: increase in the area, increase in the perimeter, and increase in the length of the radius. Daily increments of these increases were also compared, as well as the number of times each one increased over the original measurement. Chart 1 shows that about a large and small island only two measurements increased at the same rate—the perimeters and the radii. On the contrary, the areas of each island increased at different rates varying with the size of the original island. The chart of the increments (Chart 2), beginning as they do at zero, exaggerates both the similarity in the rate of increase of the perimeters and radii and the difference in the rate of increase of areas. Chart 3 shows the number of times these measurements increased over the original ones. This method fails to give linear curves, and cannot be used because differences in the original measurements always distort the answers. Epithelization, therefore, must be expressed in terms of linear extension, i.e., change in the length of the radius or change in the length of the perimeter. Inasmuch as change in the length of a perimeter is too difficult to grasp, extension of the radius will be employed.[1]

After the latent period, epithelium did not extend at a constant rate each day. Chart 4 shows the daily growth from several islands dressed with different substances. On some days there was a marked extension of epithelium while on others only small or intermediate amounts of extension

[1]Although the original area is a square, the radius of a circle of same area is used for the computation. The radius of a circle is 13 per cent longer than the half-edge of a square of the same area. This relationship is constant and the difference is small. Dr. Henry Simms has checked the mathematic accuracy of these statements.

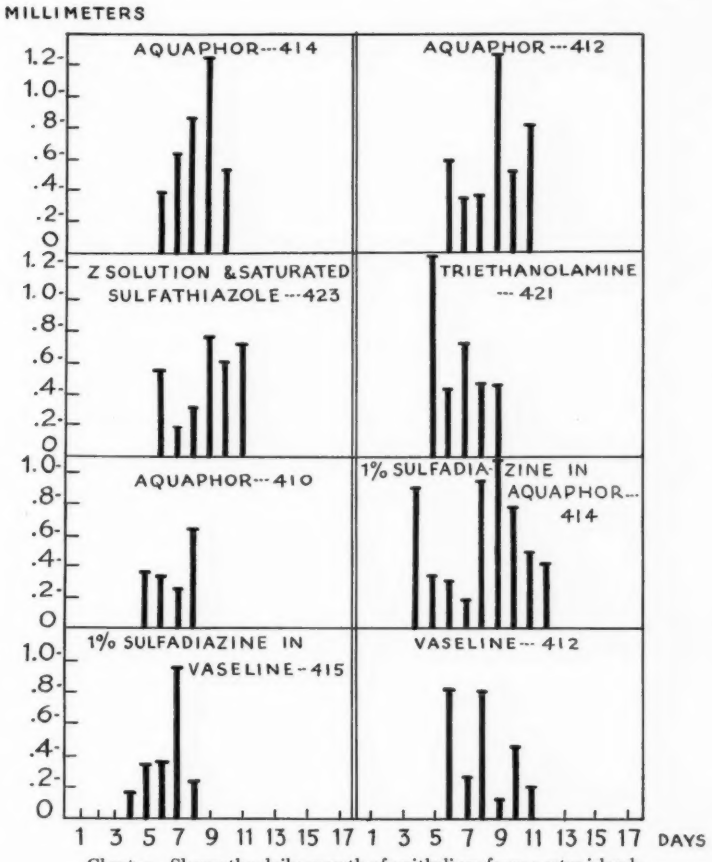


Chart 4. Shows the daily growth of epithelium from center islands dressed with various therapeutic substances. Note that in the three islands dressed with aquaphor there is no rhythm to this extension. The wound dressed with 1 per cent sulfadiazine in aquaphor illustrates a good rate of epithelization.

were recorded even when the same substances were employed. No rhythm could be found for these variations except that 2 days of marked extension seldom occurred together, and that when a good rate of epithelization was obtained throughout a period of healing by the employment of a beneficial therapeutic substance, there were fewer days with a poor amount of extension. On the other hand, even when a poor rate of epithelization was obtained there were still days of explosive extension in a general pattern of small daily increases. Infection not only stopped the rate of extension, but in some instances actually caused a regression of growth obtained. When infection subsided, subsequent extension was also explosive.

The average rate of epithelization was found to be 0.5 millimeter per day.

GROSS CHANGES DURING EPITHELIZATION

A suitable granulating base was needed to allow epithelization to begin. This base had to be free of exudate, red, not too uneven, and neither elevated above nor depressed below the surrounding skin margins.

The advancing margin of new epithelium appeared as a thin bluish white border devoid of normal pigment and hair follicles (Fig. 2). To the naked eye this margin seemed regular, although when it was viewed through a magnifying glass the edges were slightly serrated. Irregular-

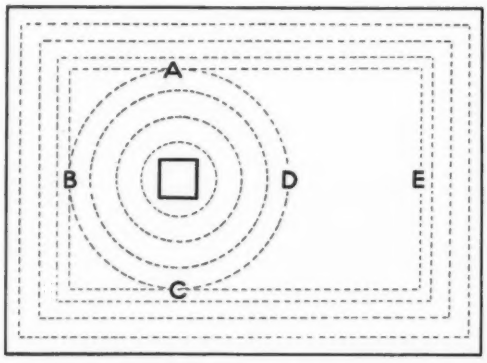


Chart 5. Schematic illustration of geometric patterns in epithelization. The outside heavy black line represents skin edges of the defect. The small square of continuous black represents the center island. The dotted lines show the extending epithelium. Actually the corners of the epithelium advancing from the edges of the defect should be slightly rounded.

ities were more marked when the surfaces of the granulations were uneven.

The very edge of the advancing margin of epithelium was often not attached to the underlying granulations and could be turned back for a very short distance by means of a cotton swab. A quick pull on this free margin would strip back the new epithelium from the granulations for a considerable distance and cause bleeding. Tearing of the free margin occurred when adherent dressings were removed. Immediately behind the margin, the new epithelium was a dull white and was thicker.

As regenerating epithelium also advanced inward from the periphery of the defect, the corners tended to round and rarely an island of epithelization would suddenly appear in the midst of the granulations. This unexpected growth apparently originated from undestroyed epithelial cells about a hair follicle or skin gland. The average linear extension from the edges of the defect was identical with that from the center island. No consistent predilection of one edge to extend more rapidly was observed in spite of the fact that the one nearer the base of the ear theoretically should have had a better blood supply.

MICROSCOPIC CHANGES DURING EPITHELIZATION

Epithelization was characterized by four microscopic changes: (1) hypertrophy of the uninjured epithelial cells at the wound edges, (2) migration of uninjured cells outward over a suitable granulating base, (3) mitotic division, and (4) restratification of the extended portion.

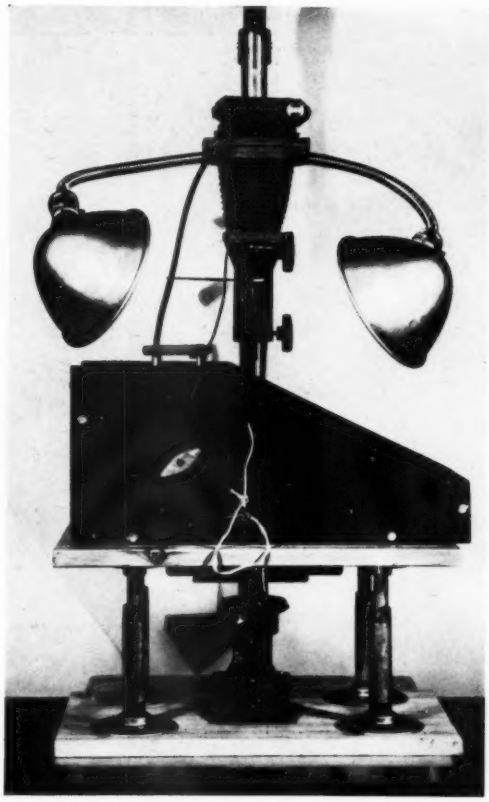


Fig. 1. Apparatus used for taking photographs.

Hypertrophy of the old epithelium at the wound edges extended backward for a distance of 3 or 4 millimeters (Fig. 3). It began to appear within 24 hours after wounding and even epithelium about adjacent hair follicles sometimes became involved. Both the nuclei and cytoplasm of the cells in all layers of skin increased in size, including those below the keratin layer which had already lost their nuclei. Mitotic figures were rare. The cells immediately beneath the pigment and the germinal layer, which ordinarily are parallel to the surface of the skin, became vertical to it. The cells in the germinal layer appeared crowded together but still contained only an occasional mitotic figure. This hypertrophy resulted in a massing of cells at the edge of the wound about the 4th day after wounding.

Following this hypertrophy, cells from the germinal layer extended laterally over the defect. These flattened into a single layer (Figs. 4 and 5).

Fig. 2. A 13 day wound in the ear of the rabbit magnified 2.1 times. The rod measures 0.5 centimeter. The outside black line denotes the original area of the wound. There has been no contraction. Inside this line is a rim of new epithelium (1½ to 2 cm.). The circle in the center was originally a square of epithelium (lying under the measuring rod) which has grown out into this shape. Between the circle and the rim are granulations appearing somewhat darker in color. The new growth of epithelium first appeared on the 6th day of healing. The rate of epithelization can be calculated from this photograph. The tip of the ear is toward the left.

The length of the extension from the stratified epithelium was considerable and beneath this extension fibroblasts began to appear parallel to the

Fig. 3. Skin wound in rat's tail—3 days old. Epithelium is just beginning to advance. The defect is on the right. The hypertrophied and thickened old epithelium is in the center. One of the hair follicles is involved.

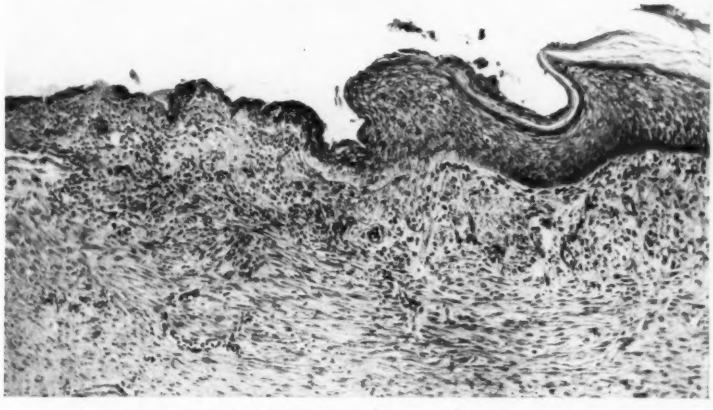


Fig. 4. The defect is on the left. The single layer of cells advancing from the germinal layer can be seen in the middle of the photograph. It can be seen extending for a considerable distance over the granulations by following the germinal layer outward from the stratified thicker portion.

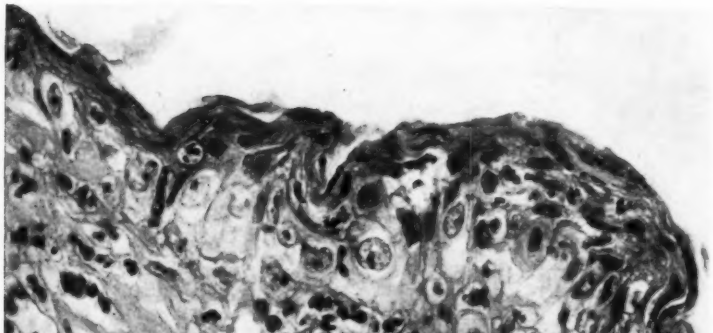


Fig. 5. High power of the extending cells, present in Fig. 4, showing their relationship to the surface of the granulations and the occurrences of leucocytes beneath them. Note the absence of mitotic figures.

Fig. 6. Newly restratified epithelium, showing the amount of keratin on its surface and the character of the cells above the germinal layer. The long axes of these cells are still vertical to the surface. On the right, pigmentation is beginning to reappear. The granulations beneath the epithelium consist largely of fibroblasts and capillaries. The reticulin fibrils are still small and are arranged in many directions.

surface and leucocytes and mononuclear cells became fewer in this zone than farther out in the granulations. Sometimes this zone of extension could be observed grossly as a clear red rim about an island.

Mitotic figures first appeared in the old uninjured epithelium at the edge of the wound. They only appeared in the cells which had already moved out over the granulations after 9 days when thickening took place into more than one layer. This

thickening occurred from the old epithelium outward decreasing in amount to that point where the cells extended in a single row. If this point were sectioned just before another ameboid extension took place, it would appear as a growing point of extending epithelium. In fact this point frequently appeared as a growing point both when epithelization was slow and when it was rapid.

Immediately behind this point, the cells not only arranged themselves in more than one layer, but those in the upper ones again turned with their axes parallel to the surface, their nuclei were lost most superficially, and keratin began to appear on the surface (Fig. 6). The reformed keratin was not as thick as over normal epithelium. After a week, pigmentation began to appear in the cells of the superficial layers. The resulting new epithelial scar was slightly thicker than the old epithelium and its rete pegs did not extend as deeply. There were no hair follicles or sebaceous glands below.

GEOMETRIC PATTERNS AND EPITHELIZATION

Epithelization advanced radially outward from the skin island and radially inward from the skin edges until the defect was resurfaced. When contact occurred between the advancing margins at points *A*, *B*, and *C* in Chart 5, lateral extension stopped and restratification took place in the adjacent areas. At the same time, however, lateral extension continued between points *D* and *E* and in the triangles bounded on the inside by *AB* and *BC*. Contact of epithelial cells with epithelial cells stopped lateral extension, therefore, but on the other hand, lateral extension continued without contact.

Tropism was not found to be responsible for a more rapid rate of epithelization when two edges approached each other. In Chart 5, for example, the angles of the triangle closed more rapidly than the area between *D* and *E*, and tropism is the usual explanation given for the rapid closure under these circumstances. The true explanation is much simpler. These areas are small and with epithelium advancing from all margins at the same average rate, naturally the rate of closure was more rapid than over the larger defect.

In these experiments, epithelization was observed for only 2 weeks and consequently the slowing and arrest of the process which follows differentiation of the granulating base was not observed. During these 14 days, however, when the granulations were still fresh, the passage of time did not affect the rate of epithelization. The rate, for example, was no more rapid when epithelization began than at the end of this time. Instead the variations were daily, and local conditions in the wound largely determined the amount of extension. Lastly no evidence was obtained that a greater rate of epithelization exists when a defect is large than when it is small.

Of course everything which has been said about epithelization in this paper is concerned with the process when there is loss of substance and not with epithelization occurring from an intact basement membrane.

SUMMARY AND CONCLUSIONS

1. Epithelization begins after a latent period of 3 to 6 days.

2. Frequent dressings prolong the length of the latent period by tearing away the advancing cells.

3. The rate of epithelization should be expressed either in terms of change in perimeter or of lateral extension from any one edge.

4. The average rate of epithelization over recently formed granulations is 0.5 millimeter daily.

5. The rate of epithelization is not influenced by the size of the defect nor is there a greater rate immediately after the start than there is 10 days later.

6. Instead the daily amount of extension of epithelium is influenced by local conditions in the wound. Bursts occur in the amount of extension without any particular rhythm.

7. Infection stops epithelization entirely.

8. A poor rate of epithelization is characterized by very small amounts of daily extension but still occasional spurts occur.

9. Microscopically epithelization is characterized by hypertrophy of uninjured epithelial cells at the edges of the wound, migration of uninjured cells outward over a suitable granulating base, mitotic division, and restratification of the extended portion. These processes are described.

10. The arrest of lateral extension of epithelium is discussed as well as the relationship of geometrical patterns to epithelization.

11. Tropism was not observed.

REFERENCES

1. AKAIWA, HACHIRO. J. Med. Res., 1919, 10: 371–413.
2. CARREL, A., and HARTMANN, A. J. Exp. M., 1916, 24: 429.
3. DANN, L., GLUCKSMANN, A., and TANSLEY, K. Lancet, 1942, 242: 95–98.
4. DOUGLAS, B. Ann. Surg., 1921, 73: 673.
5. OLSON, M., SLIDER, E., CLARK, W. G., MACDONALD, R. Exp. Biol. & Med., 1942, 49: 396–399.

CONSTRUCTION OF AN ARTIFICIAL VAGINA

WILLIAM MILTON ADAMS, M.D., Memphis, Tennessee

FROM the numerous methods of construction of the vagina which have been introduced within recent years, it is obvious that the ideal procedure has not been found. The disadvantages of the earlier methods, notably those of Baldwin and Schubert, whereby a segment of the intestine was transplanted into the artificial vaginal cavity, were the magnitude of the operation, the serious risk of infection, and the instability of the intestinal tissue lining. The newer techniques are relatively safe, yet they possess other features which leave much to be desired.

In general, the procedures in current use for construction of an artificial vagina are of two types: (1) those wherein some form of skin graft is utilized, and (2) those wherein some type of mold is inserted into the cavity, epithelization of the walls being allowed to take place spontaneously. The majority of the first type have been evolved from Graves' method of elevating two skin flaps from the labia and two from the thigh, and attaching them together and to the top of the opening created between the bladder and rectum. Multiple flaps of this type, however, are subject to necrosis at their distal ends, which in turn may lead to infection and contracture of the vaginal vault. The formation of a lining from a tubular skin graft from the inner aspect of the thigh, as advocated by Frank and Geist, is a multiple stage operation, necessitating prolonged hospitalization of the patient; moreover, in the event the flaps are successful, the lining is bulky and contains hair follicles, and because of the presence of all the skin glands, an undesirable secretion is associated. These methods likewise involve mutilation of the vulva or of the skin of the thigh, which is not an inconsiderable objection to the patient. Multiple small Thiersch grafts, employed by a number of authors, are simple of application, yet are inadequate to insure a stable, durable vaginal lining.

Operations of the second type, wherein the walls of the cavity are kept open by a mold and allowed to epithelize spontaneously, are based upon the theory that the lining thus formed is created from embryonic rests and is therefore normal vaginal mucosa. Wharton, who originated this method, has reported successful results in several cases. Such a lining, nevertheless, must inevitably contain more or less fibrous tissue and, as a consequence, lack elasticity and tend to contracture. In addition, the slow process of complete healing necessitates the prolonged use of some type of obturator. Word, in an effort to facilitate epithelization, has applied pinch grafts to the vaginal mold before its insertion into the cavity. This method is, in the author's opinion, preferable to the use of no grafts at all, though it might be expected that the intervening raw areas would be covered largely by scar tissue, as is true when pinch grafts are applied to raw areas elsewhere over the body. Frank (4) has recently suggested a nonoperative technique whereby a cavity is created gradually by successive packings with gauze, each being inserted deeper than the previous one. This procedure possesses the same disadvantage as others wherein no lining is introduced, namely, the likelihood of scar tissue formation and the danger of contracture upon removal of the packing. Further, one can seldom count on the intelligent and prolonged co-operation of the patient essential to the carrying out of the procedure.

The most desirable operation is obviously one which is simple of execution and involves the smallest risk, yet gives the patient a vaginal lining which is both pliable and stable. It would seem impossible to obtain such a lining without the use

From the Department of Plastic Surgery, University of Tennessee College of Medicine.

Fig. 1. a, The first mold made of a wire mesh frame covered with rubber sponge, to which skin graft is attached is worn for 10 days. The second mold, b, is made of acrolite, a hard, light-weight substance which causes no tissue reaction and permits cleansing of the vaginal cavity without removal. The third mold, c, is a rubber sponge covered with a condom, which is worn during the contractile period to maintain the original size of the vagina.

Fig. 2.

Fig. 3.

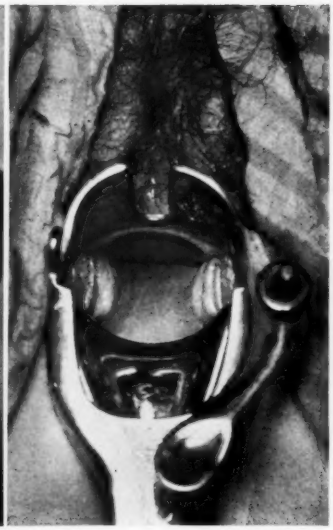


Fig. 4.

Fig. 2. Case 1. Small vaginal indentation 1 centimeter in depth. External genitalia normal.

Fig. 3. Roentgenogram showing a round vaginal obturator 1.5 inches in diameter inserted into the vagina to a depth of 6 inches 1 year after operation.

Fig. 4. Case 1. Medium size vaginal speculum inserted into the artificial vagina, showing completely epithelized wall. The mucosa is glistening, in contrast to the skin of the thigh.

of some type of skin graft large enough to cover the walls of the cavity completely. Mucosal tissue would, of course, be preferable; since a sufficient amount is not available, however, one must resort to some other type. Occasionally, a blind fistulous tract lined with normal vaginal mucosa is present; even so, the stability of such a lining would be questionable. The intermediate skin graft appears to offer the most logical solution to the problem, in that it minimizes the risk of contracture and provides a durable, elastic surface, at the same time necessitating a relatively short period of postoperative care. With this in mind, the author has employed a technique embodying the application of intermediate skin grafts of proper dimensions to form a complete lining of the cavity, which is in principle that of the Esser inlay graft. Counseller (2) reports successful results by completely lining the vaginal cavity with a free skin graft applied over a hard vulcanite mold; as recommended by McIndoe and Banister. After the mold is inserted, the vaginal orifice is closed by approximating the labia minora except for a very small opening just below the urethra for drainage. This mold is left in for 6 months, after which the patient wears a glass mold for several months longer. He states that these patients do have discomfort from the mold the first month, but are not bothered thereafter.

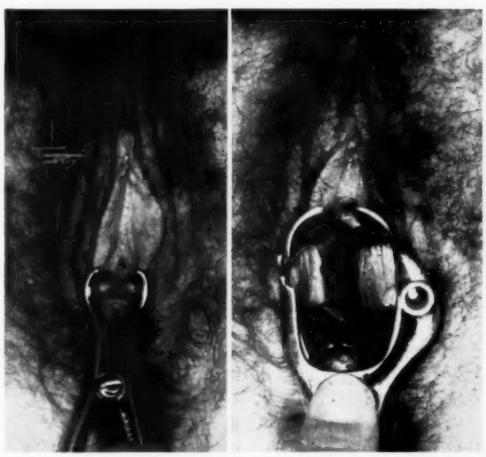


Fig. 5, left. Case 2. Small vaginal pouch 1.5 centimeters in depth and 0.5 centimeter in diameter demonstrated by means of a nasal speculum. Normal external genitalia.

Fig. 6. Case 2. Medium size vaginal speculum inserted into artificial vagina, showing cavity normal in size and completely epithelized.

Fig. 7.

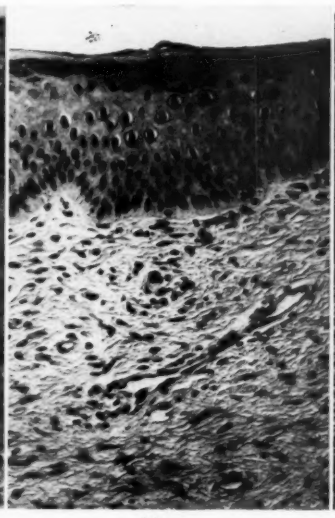


Fig. 8.

Fig. 9.

Fig. 7. Longitudinal section taken at the junction of the anterior and middle third of the posterior wall of a normal vagina in a girl 18 years of age for comparative study with skin graft lining of the constructed vagina. Note the absence of any stratum corneum or stratum granulosum. No sweat or sebaceous glands. No hair follicles. Basal cells are columnar in type. All the cells above are of the stratified squamous variety. As they near the surface they increase in size and become vacuolated and more clear. This epithelium normally varies in thickness from 150 to 200 microns.

Fig. 8. Section from artificial vagina 3 months after operation. It has the characteristics of skin except for the absence of sweat or sebaceous glands and hair follicles. There is a well developed and adherent cornified layer. The stratum granulosum varies in thickness from 3 to 5 cell layers. The papillae are few and shallow. Basal cells are simple, columnar in type, and contain many mitotic figures. Cells above are polyhedral in shape, and as they approach the surface become more flattened.

Fig. 9. Section from artificial vagina 1 year after operation. The stratum corneum is much thinner than in the 3 months' specimen and appears somewhat vestigial. The stratum granulosum layer is quite thin and rarely more than one cell layer in thickness and is occasionally absent, suggesting a decrease in its production of the cells of the corneum. There is an increased thickness of the stratum malpighii, as compared to the 3 months' specimen. The papillae are quite numerous and large. The basal cells are columnar in type, but contain comparatively few mitotic figures. Cells above are polyhedral in shape. No sweat or sebaceous glands or hair follicles noted.

Owens has recently reported a case in which he obtained excellent results by completely lining the cavity with one-half thickness skin graft; using a vulcanite form held in place by rubber tubes attached to an abdominal binder.

Two cases are here presented, in which 3 different types of vaginal molds were used. It is believed that they have definite advantage over other vaginal molds used for this purpose. The first mold is inserted at operation, the second after approximately 10 days, and the third a week or 10 days later.

The first mold consists of a chromium plated, coarse mesh wire frame 4 inches in length and 1 inch in diameter, covered by a rubber sponge 3/8 inch in thickness. A sponge is selected in which the holes are large and radiate toward the center, as the spokes of a wheel, to facilitate drainage into the cavity, should this be desirable. A groove corresponding to the size of the urethra is cut along the upper surface of the sponge to prevent pressure necrosis and fistulization of the urethra (Fig. 1, a).

This mold has several advantages over those previously used, namely: (1) it is lighter in weight and therefore more comfortable for the patient; (2) being covered with a rubber sponge, the mold permits an even pressure over the entire surface of the graft; (3) there is less likelihood of movement of the graft with motion of the patient's body; (4) drainage of any area of the cavity through the mold is possible; (5) as the opening in the mold extends throughout its length, one can check the progress of the wound at any time; and (6) irrigation, if necessary, can be carried out without disturbing the mold or the patient.

The second mold is made of acrolite, a hard, light-weight material which produces a minimum

tissue reaction. This mold is similar in shape and size to the first, being 1.5 inches in diameter and 4.5 inches long, though only ⅛ inch thick. Multiple perforations are made over its entire surface to permit cleansing of the cavity without removal of the mold. A notch is made in the outer rim to prevent interference with urination, and behind this notch the mold is grooved as a precaution against undue pressure on the urethral canal. This mold is not needed when one obtains a complete take of the skin graft, however, in the event there might be one or more small raw areas it should be used (Fig. 1, b).

The third mold consists of a rubber sponge 1.5 inches in diameter and 5 inches long, covered by a condom. This mold can be readily inserted and removed by the patient, is easily cleaned, and is worn without discomfort (Fig. 1, c).

CASE REPORTS

Mrs. D. P., an attractive white girl, aged 16 years, was referred for construction of a vagina, July 25, 1940. According to her history, she had never menstruated, although at irregular intervals during the previous 2 years she had experienced a slight low abdominal discomfort simulating menstrual pain. She had not had any serious illnesses nor any operations. She had married without knowledge of her condition, and after marriage had consulted her family physician because of inability to have intercourse. Believing that she had an imperforate hymen, the physician had attempted to correct the condition by a simple incision; it was then discovered that she had no vaginal cavity.

The patient was well developed, her breasts were of normal contour, and there was no evidence of glandular disturbance. No tumefaction was palpable in the abdomen. On bimanual examination with the finger in the rectum, a small, mobile uterus could be detected. The examination was otherwise negative. The external genitalia were normal. Just below the urethral orifice was a small indentation approximately 1 centimeter in depth (Fig. 2). This was surrounded with scar tissue, probably the result of the incision made 3 weeks before for the supposed imperforate hymen. In order to determine whether or not a vaginal fistulous tract was present, lipiodol was injected into the very small shallow pouch under pressure and a roentgenogram was made; no evidence of such a tract was observed.

Prior to operation, the intestinal tract was evacuated, that bowel movements might be delayed as long as possible after operation.

Operation. General anesthesia with ethylene gas was used. A vertical incision was begun just below the urethral os and continued down to the junction of the labia majora. With a catheter in the urethra and a finger in the rectum, an opening between the bladder and rectum was made by blunt dissection, its depth and diameter corresponding to that of the mold to be inserted subsequently, so that its surface would fit smoothly and evenly throughout. Only a thin layer of connective tissue intervened between the bladder and rectum, and extreme care was necessary in making the dissection to avoid perforation of the walls of these structures. There was no cervix or any tissue present which resembled vaginal mucous membrane.

At this point, a condom was slipped over a sponge vaginal mold (Fig. 1, c) and inserted into the newly formed cavity to control oozing of blood while the lining was being prepared. With a Blair skin graft knife, a split graft of approximately half the thickness of the skin measuring 3.5 inches in width and 7 inches in length was taken from the inner aspect of each thigh. Rubber cement was applied to a few small areas on the surface of the sponge covering the wire mesh frame (Fig. 1, a), to obviate the necessity of suture of the graft yet insure its maintenance in proper position. The graft was then applied smoothly over the mold, its raw surface being placed on the outside. With a No. 11 Bard-Parker knife blade, multiple small openings were made through the graft into the rubber sponge, to permit drainage in the event this should become necessary. The mold previously placed into the newly formed cavity to stop the small amount of bleeding, was withdrawn and the graft-covered mold was inserted, the groove in the mold being placed directly beneath the urethra. Two tension sutures of No. 2 Deknatel were passed through the labia majora to help prevent any movement of the skin covered vaginal mold. A retention catheter was introduced into the urethra, and remained in place for 10 days, to prevent contamination of the wound with urine after operation.

The cavity and mold were inspected daily for drainage. On the 5th postoperative day a slight moisture was observed, and saline irrigations of the inside of the vaginal mold were promptly instituted and carried out at frequent intervals. Neither the mold nor the patient was disturbed for these irrigations. The water remaining inside the mold after irrigation was sucked out with a glass tube attached to a bulb syringe. The mold was removed on the 10th postoperative day, and it was found that the graft had taken completely with the exception of one small area approximately 1.5 centimeters in diameter on the right vaginal wall posteriorly. The general appearance of the skin graft was typical of the usual split graft to any other part of the body at its first dressing. The retention catheter was also withdrawn at this time. The specially prepared acrolite mold, which could be removed and replaced as necessary for hygienic purposes, was then introduced into the cavity (Fig. 1, b).

The small area on the vaginal wall, where the skin graft failed to take, was watched from day to day for an epithelization of vaginal mucous membrane or any cellular changes which might suggest regeneration from embryonic vaginal rests, which, according to Mijsberg, Koff, and Vilas, are concerned in the formation of normal vaginal mucosa. The area presented all the characteristics of a raw, granulating wound, as was expected. Had there been any of the embryonic rests, I feel sure that its surface would have resembled that of normal vaginal mucosa. Healing took place as in the ordinary wound, from the periphery inward. Two or three weeks later some scar tissue reaction was observed in the area, necessitating digital massage to prevent contracture.

The acrolite mold was removed after 1 week, and a solid rubber sponge mold covered with a condom was inserted (Fig. 1, c). This mold caused no discomfort and could be easily removed and reinserted by the patient as desired. It is worthy of mention that both the acrolite mold and the rubber sponge mold remained *in situ* without the use of a binder or any other support.

At the end of 3 or 4 weeks the graft began to exhibit some of the characteristics of normal mucosa, being somewhat pink in color and sufficiently moist to present a naturally glistening surface. Tactile sensation was elicited throughout the vaginal wall by the gentle application of a small cotton swab to different points. The patient was allowed to have intercourse after 3 months. She did not experience an orgasm for several weeks after she began having intercourse. The husband reported complete satisfaction from the beginning.

The rubber sponge mold was worn continuously for 3 months. The following 3 months the mold was worn about half the time, and for the next 3 to 4 months the mold was inserted at irregular intervals for a few hours at a time.

The patient returned May 12, 1941, 10 months after construction of the vagina, because of a moderately severe low abdominal cramping and an associated dull pain in the breasts, more or less, at monthly intervals. Believing that these symptoms were related to her menstrual dysfunction, she was referred to a gynecologist, who advised exploration. At operation a small bicornuate uterus was found. Both ovaries and tubes were normal. A hysterectomy was performed. The ovaries and tubes were not disturbed. Each horn of the uterus measured 9 centimeters in length and 1.5 centimeters in diameter. At the distal end of the left horn there was a small cyst 1 centimeter in diameter containing thin, clear, yellowish fluid. The pathologist reported that the mass was solid throughout, with no evidence of a cavity.

One year after operation a round vaginal obturator 1.5 inches in diameter could be inserted easily to a depth of 6 inches without any discomfort to the patient (Fig. 3). The lining of the cavity was pink, moist and glistening, closely resembling normal vaginal mucosa (Fig. 4). It is now 27 months since the vaginal construction and the patient is well and happy.

CASE 2. Miss O. S., white, aged 31 years, was referred by a gynecologist, March 28, 1941, for congenital absence of the vagina. She had consulted the gynecologist because of a severe low abdominal cramping. She gave a history of having had similar attacks since she was 13 years of age. These attacks, as described, were suggestive of menstrual cramping and varied in duration from 1 to 3 days and were from 3 weeks to several months in occurrence.

On discovering the vaginal anomaly, and being unable to palpate any of the pelvic organs rectally, the gynecologist explored the patient's abdomen. A bicornuate uterus, each horn of which measured 8 centimeters in length and 1.8 centimeters in diameter, was found and removed. Both tubes and ovaries were normal and were left *in situ*. There was no cervix. The pathologist reported that the two uterine horns were imperfectly fused in the midline, and no cavity could be demonstrated in either.

At the patient's first visit, prior to the hysterectomy, the author found a rudimentary vagina 1.5 centimeters in depth and 0.5 centimeter in diameter (Fig. 5). The external genitalia were normal, and the patient otherwise presented normal feminine physical characteristics. Since there was no occasion for correction of the defect at that time, an operation was not advised.

The patient returned, April 20, 1941, stating that she wished to have a vagina constructed, as she intended to be married in the near future. The vagina was constructed in the same manner as in the first case presented. In carrying out the dissection for the cavity, a search was made for a vaginal tract, though none was found. Two medium thick skin grafts, each approximately 3.5 by 7 inches in diameter, were taken from the thighs and applied over the sponge covered wire mesh frame (Fig. 1, a), and the mold was inserted into the opening. At the conclusion of the operation, a retention catheter was placed in the bladder. Both the mold and the catheter were removed on the 11th postoperative day.

Postoperative drainage was negligible, and upon removal of the mold, the lining was found to have adhered throughout. Since the graft had taken completely, it was not felt necessary to insert the acrolite mold, as was done in the first case. The rubber sponge, covered with a condom (Fig. 1, c) was placed in the cavity immediately. During the remainder of the patient's stay in the hospital, this mold was removed twice daily for cleansing of the cavity. She was discharged from the hospital 14 days after operation. The rubber sponge mold was worn continuously for 3 months. During the next 4 months it was worn only during the night and for the next few months it was inserted only at varying intervals as a check and precaution against any diminution in size of the vaginal cavity.

The patient was last seen 19 months after operation. The vaginal cavity still maintained its original size and only after a very close detailed examination could one distinguish it from a normal vaginal mucous membrane (Fig. 6). She stated that sexual intercourse was completely satisfactory and that she had an orgasm with each act.

A comparative study was made of the epithelial lining of the constructed vagina with that of the normal vaginal mucous membrane. The surface of the grafted lining during the first few weeks has all the characteristics of a split skin graft applied to the external surface of the body. It soon begins to lose the gross appearance of skin and takes on a pink, moist, glistening appearance. During the first 2 or 3 months the surface is rather smooth, after which irregular shallow furrows begin to develop, which closely resemble the rugae of a normal vagina. The secretion of the constructed vagina has never suggested that of the sweat or sebaceous glands of normal skin.

For comparative microscopical study, a specimen was taken from the vaginal wall of a healthy, nulliparous girl, 18 years of age (Fig. 7). Sections were also taken from the epithelial lining of the constructed vagina at 3 months (Fig. 8) and 1 year after operation (Fig. 9). All specimens were taken at the junction of the anterior and middle one-third of the posterior vaginal wall.

In a normal vagina there is no stratum corneum or stratum granulosum. In the artificial vagina at 3 months, there is a stratum corneum which resembles that of normal skin, being quite smooth and adherent. At 1 year it is much thinner and appears somewhat vestigial.

In the artificial vagina, the stratum granulosum at 3 months appears quite active varying in thickness from 3 to 5 cell layers. At 1 year, it is quite thin, rarely more than one cell layer in thickness and occasionally absent, suggesting a decrease in its production of the cells of the corneum. The stratum malpighii at 3 months is about one-half to two-thirds the thickness of the 1 year old specimen. The papilli (rete-pegs) at 3 months are few and shallow and at 1 year are numerous and larger. The basal cells are simple columnar in type and at 3 months there are many mitotic figures, as compared to only a few at one year. The cells above the basal layer become polyhedral and as they approach the surface increase in size and become more flattened.

No sweat glands, sebaceous glands, or hair follicles were noted in either specimen. The subepithelial layer, which is composed of loose connective tissue, appears the same in all 3 specimens.

The basal cells of the mucous membrane of the normal vagina are columnar in type. All the cells above the basal layer, however, are of the stratified squamous variety. As the cells near the surface they increase in size and become vacuolated and more clear. Maximow and Bloom, in describing the normal vaginal mucous membrane, state that the epithelium is of the stratified squamous variety and has a thickness of 150 to 200 microns. Under normal conditions the superficial cell layers in primates do not show cornification, although they contain granules of keratohyalin. The nuclei usually remain stainable and the cells become loaded with glycogen and fat. In a prolapsed vagina, when the mucous membrane is exposed to air, the superficial cells are cornified as in the epidermis.

Embryologically, the mucous membrane of the vagina and the skin are both of epidermal origin, which may well explain why the mucous membrane when exposed to air over a long period of time, as in a prolapsed vagina, becomes cornified like the epidermis of the skin. This being true, it seems reasonable to assume that the reverse process might take place, when skin placed under the same environment as that of the normal vaginal mucosa would lose the characteristics of normal skin and take on the appearance of the epithelial lining of a normal vagina.

SUMMARY

A technique is described for complete construction of an artificial vagina in one operation whereby the newly formed cavity is completely lined with a thick split graft ranging from thin to medium.

It is felt that the three types of vaginal molds used play an important part in the success of the operation. The first, which is covered over with a half thickness skin graft and inserted into the newly formed cavity immediately, is made of rubber sponge surrounding a wire framework. This mold is comfortable, very soft, light in weight and affords an even and constant pressure on the skin graft. The second mold, made of acrolite and also light in weight, has multiple perforations permitting vaginal irrigations without removal. The third, consisting of a rubber sponge covered with a condom is worn until all danger of contracture of the skin graft has passed. This mold may be easily removed and reinserted by the patient. All molds described remain in place without the aid of an external brace or support.

Two cases are presented in which excellent results were obtained by this method, both patients reporting satisfactory normal sexual intercourse.

REFERENCES

1. Baldwin, J. F. Ann. Surg., 1904, 40: 398.
2. Counseller, V. S. S. Clin. N. America, 1939, 19: 1047.
3. Esser, J. F. S. Esser Inlay. Leiden, Holland: E. J. Brill, 1940.
4. Frank, R. T. Am. J. Obst., 1938, 35: 1042.
5. Frank, R. T., and Geist, S. H. Am. J. Obst., 1927, 14: 712.
6. Graves, William P. Gynecology. 4th ed., p. 794. Philadelphia: W. B. Saunders Co., 1928.
7. Koff, Arthur K. Development of the Vagina in the Human Foetus, Carnegie Contribution to Embryology. 1933, 24: 59.
8. Maximow and Bloom. Textbook of Histology. 4th ed. Philadelphia: W. B. Saunders Co., 1942.
9. McIndoe, A. H. and Banister, J. B. J. Obst., Gyn. Brit. Empire, 1938, 45: 490.
10. Mijsberg, W. A. Zschr. ges. Anat., 1924, 74: 684.
11. Owens, Neal. Surgery, 1942, p. 139.
12. Schubert, G. Surg. Gyn. Obst., 1914, 19: 376.
13. Vilas, E. Zschr. Anat. Entw. 1932, 98: 263.
14. Wharton, Lawrence R. Ann. Surg., 1938, 107: 842.
15. Word, Buford. South. M. J., 1940, 33: 293.

EDITORIALS

SURGERY
Gynecology and Obstetrics

FRANKLIN H. MARTIN
Founder and Managing Editor
1905–1935

LOYAL DAVIS, EDITOR

Associates
SUMNER L. KOCH MICHAEL L. MASON

DONALD C. BALFOUR, *Associate, Editorial Staff*

JUNE, 1943

THE RELATIONSHIP OF FRACTURES TO SEVERE PAINFUL JOINT LESIONS OF THE LOWER EXTREMITY

WITH the increased knowledge of various types of complications arising from fractures adjacent to joints, a wider realization of the importance of more accurate and complete reduction of all fractures adjacent to joints of the lower extremity has developed. Whether it be a fracture adjacent to the hip, the knee, or the ankle, or of the midtarsal bones, a traumatic arthritis is likely to result which may in time cause a considerable amount of disability.

In the case of the hip joint, it is the fractures of the acetabulum which are particularly likely to cause such a complication. Aseptic necrosis may develop after dislocations or fractures of the neck or head, and after these have occurred it is very common for a variable degree of traumatic arthritis to develop.

Any fracture about the knee joint and particularly those fractures which have caused cracks or fissures into the joint, so that the articular surfaces are damaged, may lead to traumatic arthritis. Even more important from this standpoint are fractures through the condyle or through the tibial plateaus, which cause the normal alinement of the knee joint to become distorted. Unless the normal alinement is re-established and the axis of rotation is brought back to its normal place, constant attrition of the joint surfaces will follow, and in time a certain degree of traumatic arthritis will develop which eventually will cause severe painful arthritis to develop in the knee joint.

In fractures about the ankle joint, and particularly Pott's fractures and trimalleolar fractures, similar mechanical factors are concerned. If such fractures are imperfectly reduced they may for a while appear to give little trouble, but in time wear and tear on the joint surfaces will result in a painful arthritic joint for which little can be done except arthrodesis. In more severe fractures of this type, with severe damage to the joint surface at the time of injury, such a result may develop in spite of accurate reduction of the fracture.

The disabling effects of fractures of the calcaneus are well known. Such effects can arise from traumatic arthritis as well as from malalinement and exostosis about the bone, with or without complete reduction. It is rare that a fractured calcaneus heals completely without the causation of any disability.

Fractures of the talus, although not so common as fractures of the calcaneus, are even more of a source of painful disability. Besides the traumatic arthritic changes, at times severe aseptic necrosis may develop in a portion of the fractured talus. If it is not recognized,

and the patient is allowed to use the foot, such a condition may lead to severely disabling arthritis. Only with perfect reduction and retention past the time in which such complications develop, can the more troublesome late effects be avoided.

One has only to see a few of these painful joints developing several months to several years after fractures, about the joints of the lower extremities in particular, to realize the importance of putting forth a greater effort toward restoration of the fragments to as nearly perfect position as possible, and then the need of preventing full weight-bearing until the joint surfaces have had an opportunity to heal completely. If these rules are adhered to, better long range results after such injuries will be obtained. RALPH K. GHORMLEY.

THE SURGEON'S LIBRARY

REVIEWS OF NEW BOOKS

IN *Clinical Anesthesia*,[1] John S. Lundy has presented the medical profession with nearly 800 pages of very readable, practical, and timely information on a subject in which he is an authority and to which he has made many original contributions. The book represents his extensive personal experience of more than 17 years as head of the section on anesthesia, Mayo Clinic, covering more than 300,000 cases. This experience also spans the events in the development of anesthesia as a recognized medical specialty, culminating in the establishment in 1937 of the American Board of Anesthesiology for examination, certification, and control of specialty training in this field.

Of particular interest to the surgeon is the opening chapter, in which the choice of anesthetic agents and methods for various operations is carefully discussed in connection with 10 ingenious charts, which present a check list of approval or disapproval of each anesthetic method in relation to the possible operations in each region of the body and in relation to the patient's physical condition.

Two hundred pages are devoted to the principles and techniques of local, regional, and spinal anesthesia, with numerous illustrative diagrams. Those who have had access to Labat's *Regional Anesthesia* may miss its wealth of detail and illustration on local blocks, but Lundy surpasses former authors in his careful exposition of spinal and sacral block anesthesia. Every surgeon or anesthetist reviewing the two chapters describing Lundy's technique of spinal puncture and principles of the single dose diffusion method will find emphasis on many valuable and often neglected points. For operations requiring long duration of anesthesia Lundy describes his use of Lemmon's "continuous" spinal technique.

Over 200 pages are devoted to general anesthesia, including a careful treatment of the methods of inhalation, rectal, and intravenous administration. Most valuable is the author's discussion of the intravenous method with sodium pentothal. Lundy has had the most extensive experience with this agent and method (nearly 25,000 cases reported to 1941) since his introduction of the intermittent injection technique in 1934. Intravenous anesthesia is growing in popularity and use due to its many advantages, and holds promise of being quite useful in military and naval surgery. All who intend employing this method should read Lundy's text for information on important precautions in technique, and for the unusual effects and difficulties which may be encountered. Special chapters are included on intratracheal technique, and on anesthesia in dentistry, obstetrics, and neurosurgery.

Since the military anesthetist, and frequently the civilian, as well, is responsible for intravenous fluid therapy, including blood, plasma, and serum transfusions, and for apparatus and instruments in the operating room—their care, sterilization, and method of use—Lundy's 6th chapter serves as a valuable manual of instructions to operating room personnel on this subject. The author's oscillatory method of taking blood pressure without a stethoscope is simple and convenient. Chapter 23 discusses intravenous therapy and outlines the management of a blood bank and transfusion service. Feeling that those responsible for anesthesia should be skilled in venipuncture, the author describes several techniques for facilitating puncture of difficult veins. Resuscitation procedures are treated in a separate chapter.

The book concludes with several chapters on anesthesia statistical methods, including an analysis of experience at the Mayo Clinic from 1924 through 1940, the chemistry of anesthetics and related drugs, a historical chronology, conversion tables, a method of gas analysis for oxygen tent control, and a useful bibliography of books recommended for additional reading supplementing the specific citations ending each chapter. The book contains 266 illustrative figures and 50 charts or tables.

Lundy's emphasis on the clinical problems of anesthesia is exemplified by the frequent introduction of interesting case histories and specific incidents in the author's experience which serve as colorful illustrative material.

The text is replete with practical points and refinements of technique which have not occurred to the casual reader, who may take note and apply them with benefit to both patient and surgeon. That the book summarizes the author's own personal beliefs and experiences is shown by the exclusion from detailed consideration of certain methods, agents and techniques which he has tried but found dangerous, unsatisfactory, or unnecessary.

There has long been a need for this modern treatise on American anesthetic methods. It is fortunate to have Lundy's book available as a companion text and reference for the current courses in anesthesia for medical officers of the armed services. *Clinical Anesthesia* is heartily recommended for addition to the current working library of surgeons and physician anesthetists both at home and abroad.

HUGH O. BROWN.

[1] CLINICAL ANESTHESIA; A MANUAL OF CLINICAL ANESTHESIOLOGY. By John S. Lundy, B.A., M.D. Philadelphia and London: W. B. Saunders Co., 1942.

AS noted in the preface, *Traumatic Surgery of the Jaws*[1] is presented to assist the dentist in his preparation for first aid and emergency treatment of jaw injuries. However, any general surgeon who may be concerned with the treatment of these will find much of interest and value in it, though he will doubtless be inclined to skip some of the elementary treatises on shock, burns, anesthesia, osteogenesis, etc. The appearance of this book is timely, as reports indicate the occurrence of large numbers of facial injuries in the present mechanized warfare.

The book is well written, and the illustrations are excellent. The author concurs with the increasingly prevailing opinion that complicated dental splints are neither necessary nor desirable in the treatment of jaw fractures, and admirably refrains from their description. However, seven methods of interdental wiring are described, not all of which seem to possess intrinsic advantages over the others in any given situation. The necessity for, and evolution of, new methods of, direct skeletal fixation for edentulous fragments are noted.

From the surgeon's point of view, a more inclusive work dealing with the care of all soft tissue and bony injuries about the face and jaws might be preferable. Extensive and serious lacerations, depressed orbital floors, and compound nasal injuries are not infrequently associated with severe jaw injuries, and their care may be so intimate as to be almost inseparable.

Minor faults include the statement that "syphilis is an important cause of nonunion," the lack of attention to surgical drainage of infections which may occur around fractures, and the description of the treatment of ununited fractures in four sentences. These do not detract greatly from the general utility of the volume and the recommendation of it.

FRANK MCDOWELL.

THE individual manuals of the series of which *Abdominal and Genito-Urinary Injuries*[2] volume is one are prepared under the auspices of the various subcommittees of the committee on surgery and edited by the committee on information of the National Research Council. The committee on surgery is composed of Drs. Evarts A. Graham, chairman, Irvin Abell, Donald C. Balfour, George E. Bennett, Warren H. Cole, Frederick A. Coller, Robert H. Ivy, Herman L. Kretschmer, Charles G. Mixter, Howard C. Naffziger, Alton Ochsner, I. S. Ravdin, and Allen O. Whipple. The committee on information includes Drs. Morris Fishbein, chairman, J. J. Bloomfield, John F. Fulton, Richard M. Hewitt, Ira V. Hiscock, Sanford V. Larkey, and Robert N. Nye.

In this volume the section on "Abdominal Injuries" has been prepared by Ambrose H. Storck and contains 11 chapters dealing with "Abdominal Wounds and Modern Warfare," "General Considerations," "Study and Estimation of Status of Patients with Known or Suspected Abdominal Injuries," "General Care of Patient, Including Preoperative Preparation," "Selection of Patients for Operation," "Preanesthetic Preparation and Anesthesia," "Operative Procedure," "Wounds of Specific Structures and Organs," "Postoperative Treatment," "Complications, and Results, Mortality and Statistics."

The section on "Genito-Urinary Injuries" was prepared and edited by the subcommittee on urology of the committee on surgery. This subcommittee is composed of Herman L. Kretschmer, chairman, William F. Braasch, Frank Hinman, Homer G. Hamer, Oswald S. Lowsley, and Albert J. Scholl, with contributions by Clark M. Johnson and H. M. Weyrauch.

This volume has admirably succeeded in its purpose in conveying to its readers in the smallest compass the greatest amount of practical surgical counsel dealing especially with war injuries of the abdomen and of the genitourinary tract, the evacuation of wounded, types of missiles, and the mechanism of wound production with and without penetration. Shock and hemorrhage are considered. The diagnosis of abdominal injuries is thoughtfully outlined. The chapter on operative procedure contains much useful and practical information. The illustrations are excellent and informative, and the references at the end of each chapter are pertinent and valuable. The editors of the next edition will no doubt correct the duplication of presentation of some of the genitourinary injuries in the two parts of the volume.

In the opinion of the reviewer this small book is an important contribution to the war effort and that it should prove of value to all medical officers in the armed forces and to their patients.

FREDERICK CHRISTOPHER.

THE manual entitled *Ophthalmology and Otolaryngology*[3] prepared under the auspices of the National Research Council fulfills rather well its purpose of giving simply, graphically, and not too technically such fundamental knowledge as may be necessary in the field for men without specialist training. Especially does the first section give a well written, well organized, and understandable coverage of methods of examination and medical and surgical care of eye conditions likely to occur in military practice. Discussions of traumatic and chemical injuries, technique of local anesthesia and the simpler surgery of the lids and orbit are good.

The section on otolaryngology is somewhat uneven and some chapters seem to have been hurriedly written. The selection of material and its emphasis for such a manual must have been difficult but one might question, for instance, why mastoiditis is only casually mentioned while considerable space is given to the rather technical discussion of petrositis and operations for its relief. The chapters on wounds and

[1] TRAUMATIC SURGERY OF THE JAWS; INCLUDING FIRST-AID TREATMENT. By Kurt H. Thoma, D.M.D. St. Louis: C. V. Mosby Co., 1942.

[2] ABDOMINAL AND GENITO-URINARY INJURIES. A Military Surgical Manual Prepared under the Auspices of the Committee on Surgery of the Division of Medical Sciences of the National Research Council. Philadelphia and London: W. B. Saunders Co., 1942.

[3] OPHTHALMOLOGY AND OTOLARYNGOLOGY. Prepared and edited by the Subcommittees on Ophthalmology and Otolaryngology of the Committee on Surgery of the Division of Medical Sciences of the National Research Council. Philadelphia and London: W. B. Saunders Co., 1942.

fractures involving the sinuses, the facial bones and the temporal bone are especially good.

Military surgeons and men in civil practice away from the larger centers should find this work valuable.

THOMAS C. GALLOWAY.

IN the autobiography *The Time of My Life*[1] the author has painted a very vivid picture of his colorful life which should prove to be a real inspiration to the underprivileged youth.

As a young orphan he started his career as a newspaper boy on the Bowery, living in an unwholesome atmosphere. His early reading embraced such novels as *Deadwood Dick*, *Old Cap Collier*, and many others, the heroes of which stimulated his lust for adventure. Picked up by a truant officer he was taken to an agency, together with other homeless urchins, given his first bath in 2 years and a suit of clothes, after which he was sent to a farm in Iowa. Growing tired of this dull life he ran away, and this was the beginning of his extensive travels. Possessing a restless spirit, to which he gave full rein, he seemed dissatisfied in his early years with the conventional form of life, being impelled to rove from one part of the country to another, traveling "via the rods and side-door Pullmans." His urge was satisfied in part when he shipped aboard the "Escobar" filibustering arms to Cuba during the insurrection preceding the Spanish-American war.

In the course of his wanderings an accidental contact with an intoxicated St. Louis physician laid the foundation for a change in the course of his life. While this doctor was an alcoholic rake he was nevertheless a cultured and, at one time, an outstanding member of his profession. Taking a liking to the boy he gave him employment in his home and afforded him access to his extensive library. In fact this doctor proved to be the boy's chief inspiration to study medicine. But after a year's sojourn there he again started on his restless wandering until he finally contacted the superintendent of an asylum in Texas, who gave him work as a painter and as a helper in the pharmacy. Here he received an added incentive to take up medicine.

After working his way through a medical college and an interneship Dr. De Vighne secured a one year assignment as a government sanitary inspector of the native races of Alaska at a salary of $150.00 per month and traveling expenses. This experience served as a good foundation for his general practice in the territory. He soon sent for his fiancée whom he married promptly after her arrival.

The author's description of the early history of Alaska, of the country itself, of the habits and mode of life of its people and the crude conditions he faced in his busy practice is an interesting story in itself. He watched the country develop from a rough and tumble mining camp population and Indian villages to its present exalted state.

As Alaska developed he grew with it, keeping abreast of his profession by refresher courses in New York or Boston every other year. In addition to his large general practice he served as territorial commissioner of health, secretary of the medical examining board, and secretary of the Alaska Medical Society.

The story is interestingly written and commends itself to laymen and doctors alike.

CHARLES E. KAHLKE.

THE compact volume *Roentgen Treatment of Diseases of the Nervous System*[2] by Dr. Dyke covers the field most thoroughly. It begins with the effects of γ irradiation and x-rays on nervous tissue. The irradiation therapy of brain tumors is next considered, and this section comprises the major portion of the volume. Inflammatory diseases of the nervous system, spinal cord tumors, extradural spinal cord tumors, syringomyelia, neuralgias and neuritis, and herpes zoster are then discussed in the order given. Worthy of special commendation is the manner in which technical details of the irradiation therapy are described. The therapy may be followed in detail by any qualified radiologist and thus he may obtain the maximum of benefit from the discussions of the authors' experiences. This feature is in contrast to a number of previously published articles and monographs which often deal with details of technique in an ambiguous manner. Another very commendable feature is the highly objective manner in which results of irradiation therapy are evaluated. The monograph is written in a clear concise manner; it is well printed and the illustrations and very graphic charts aid in the proper emphasis of the various questions under discussion. This excellent contribution adequately fulfills the need for which it was intended, i.e. to review the facts concerning irradiation therapy of diseases of the nervous system "in order to restore this valuable form of therapy to its proper place." It should be in the library of every radiologist, neurologist, and neurosurgeon.

ALEXANDER BRUNSCHWIG.

THE 11th annual *Year Book of Radiology*[3] is a compilation of abstracts of the literature on radiology of the 12 months preceding publication. The section on diagnosis covers the body systemically under 10 headings, plus a chapter on technique and one on teaching and principles of practice. The abstracts are concise, but leave no important detail or factor undescribed; in few instances does the editor refer the reader back to the original article. Accompanying the abstracts is a profusion of well reproduced roentgenograms, positive copies of roentgenograms, photographs, and line drawings. The only gross misprint noted was in the chapter on skull,

[1] THE TIME OF MY LIFE; A FRONTIER DOCTOR IN ALASKA. By Harry Carolos De Vighne. Philadelphia and New York: J. B. Lippincott Co., 1942

[2] ROENTGEN TREATMENT OF DISEASES OF THE NERVOUS SYSTEM. By Cornelius G. Dyke, M.D., F.A.C.R., and Leo M. Davidoff, M.D., F.A.C.S. Philadelphia: Lea & Febiger, 1942.

[3] THE 1942 YEAR BOOK OF RADIOLOGY. DIAGNOSIS edited by Charles A. Waters, M.D., and Whitmer B. Firor, M.D.; THERAPEUTICS edited by Ira I. Kaplan, B.Sc., M.D. Chicago: The Year Book Publishers, Inc., 1942.

sinuses, and mastoids. An abstract of an article on origin and management of occipitoposterior position in labor, has crept in, which contains no reference whatever to radiology.

The section on therapeutics is divided into 16 chapters. The editor's introductory chapter covers in general the remainder of the section and correlates the main points and conclusions of the abstracted articles which follow. Its organization makes this chapter as easily read as a textbook. Following many of the abstracts the editor discusses the article, concurring or differing with the author, enlarging on a point, citing previous references, and adding the benefit of his experience. In the treatment of malignant growths he is not partial to x-ray, radium, or surgery at the expense of either of the other two; this attitude makes his viewpoint all the more valuable.

The book is an excellent reference source and should be available to everyone interested in the practice of the specialty. E. L. JENKINSON.

MANY well known authors have contributed to this symposium monograph.[1] A large part of the book comprises papers which were presented at the annual meeting of the American Human Serum Association held in June, 1941, at Cleveland. In certain cases the results of additional work which was done by the authors between the time of the presentation of the papers and the reading of the proof were introduced. The book contains much interesting and valuable information. It can be read and understood both by the specialist and the individual who may be seeking an answer to problems relative to the use of whole citrated blood, blood plasma, blood serum, and other blood substitutes. The last chapter is a well written summary. It contains such information as "the successful management of shock requires early recognition and effective measures for breaking the vicious circle. These will be directed toward removing the cause, toward increasing the blood volume and toward relieving anoxia." The advantages and disadvantages of the four general methods for preservation of plasma and serum are discussed. Hemoglobin, serum albumin, and casein digest as blood substitutes are considered. A good presentation is made of the storage, transportation, and administration of whole blood. The Rh factor, and the specific A and B factors, both of which are new to many individuals, are readily understandable by reading this book. The use of Group o blood withdrawn from so called universal donors is discussed. This book is valuable for the general practitioner and specialist alike; it is interesting, informative, and later editions will be looked for. T. H. SELDON.

[1]BLOOD SUBSTITUTES AND BLOOD TRANSFUSION. Edited by Stuart Mudd, M.A., M.D., and William Thalhimer, M.D. Springfield, Ill., and Baltimore, Md.: Charles C. Thomas, 1942.

THE little book of 354 pages *Recent Advances in Obstetrics and Gynæcology*[2] by Bourne and Williams does not claim to be a compendium of obstetrics and gynecology. It takes up the important chapters in both fields and discusses the progress which has been made in recent years. The author does not limit himself to the work of the British clinics but work done on the continent and in America is frequently reported. In the obstetrical portion of the book no attempt is made to cover the field of obstetrics but such subjects as disproportion, anemia, version, chemotherapy, analgesia, and puerperal sepsis are considered. The chapter on pelvimetry summarizes very well the work which has been done in a number of clinics in the development of pelvimetric methods, including a review of radiological pelvimetry. The management of puerperal sepsis, including a consideration of the present status of chemotherapy, is thoughtfully presented.

In the gynecological section, 39 pages are devoted to cancer and a well organized presentation of present day therapy is given. Radiological statistics from a number of well known clinics are given. The comparison of results of extended operation in cancer of the cervix and radiotherapy is dispassionately given, the author's intention being evidently to present the facts to informed readers for their own evaluation. Sufficient information concerning the present day methods of irradiation is given to indicate the techniques which have been tried in the most active clinics.

Sterility and infections of the cervix and vagina both receive attention. The treatment of the latter is sensible considered without introducing any but the more useful methods. A timely caution appears concerning the proper employment of cauterization and conization. The chapter on hormones must be commended. The author travels safely through the quicksands of the consideration of the rarer ovarian tumors. While opinions vary concerning certain of the phases of this subject, especially as to certain points of histogenesis, this chapter is sane and sound.

Radiology as applied to gynecology is summarized and there is a brief consideration of physiotherapy.

A few typographical errors appear, for instance, the names of Wertheim and Bumm are misspelled, the former in one place only. On page 292 the use of the word "destroyed" instead of "described" causes an unfortunate distortion of meaning. These faults may easily be corrected in a later edition.

The book may be recommended to physicians, preferably to those who already have some knowledge of the fields presented, as a concise and accurate review of the progress of recent years. It should be a useful little volume. W. C. DANFORTH.

[2]RECENT ADVANCES IN OBSTETRICS AND GYNÆCOLOGY. By Aleck W. Bourne, M.A., M.B., B.Ch. (Camb.), F.R.C.S. (Eng.), F.R.C.O.G., and Leslie H. Williams, M.D., M.S. (Lond.), F.R.C.S. (Eng.), F.R.C.O.G. 5th ed. Philadelphia: The Blakiston Co., 1942.

BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgement must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

BLOOD GROUPS AND TRANSFUSION. By Alexander S. Wiener, A.B., M.D. 3d ed. Springfield, Ill., and Baltimore, Md.: Charles C. Thomas, 1943.

A TEXT-BOOK OF PATHOLOGY; AN INTRODUCTION TO MEDICINE. By William Boyd, M.D., LL.D., M.R.C.P., Lond., Dipl., Psych., F.R.S.C. 4th ed. Philadelphia: Lea & Febiger, 1943.

CLINICAL ROENTGENOLOGY OF THE CARDIOVASCULAR SYSTEM. By Hugo Roesler, M.D., F.A.C.P. 2d ed. Springfield, Ill., and Baltimore, Md.: Charles C. Thomas, 1943.

TRANSURETHRAL PROSTATECTOMY. By Reed M. Nesbit, M.D., F.A.C.S., with a chapter on the Vascular Supply of the Prostate Gland by Rubin H. Flocks, M.D. Springfield, Ill., and Baltimore, Md.: Charles C. Thomas, 1943.

OUTLINE OF ROENTGEN DIAGNOSIS; AN ORIENTATION IN THE BASIC PRINCIPLES OF DIAGNOSIS BY THE ROENTGEN METHOD. By Leo G. Rigler, B.S., M.B., M.D. 2d ed. Philadelphia, London, Montreal: J. B. Lippincott Co., 1943.

CLINICAL SIGNIFICANCE OF THE BLOOD IN TUBERCULOSIS. By Gulli Lindh Muller, M.D. New York: The Commonwealth Fund, 1943.

A MANUAL OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY. By Howard Charles Ballenger, M.D., F.A.C.S. 2d enl. rev. ed. Philadelphia: Lea & Febiger, 1943.

VICTORIES OF ARMY MEDICINE; SCIENTIFIC ACCOMPLISHMENTS OF THE MEDICAL DEPARTMENT OF THE UNITED STATES ARMY. By Edgar Erskin Hume. Philadelphia, London, Montreal: J. B. Lippincott Co., 1943.

SYNOPSIS OF DISEASES OF THE SKIN. By Richard L. Sutton, M.D., and Richard L. Sutton Jr., M.D. St. Louis: The C. V. Mosby Co., 1942.

AIDS TO SURGICAL ANATOMY. By J. S. Baxter, M.B., M.Sc., F.R.C.S.I. 2d ed. Baltimore: The Williams & Wilkins Co., 1942.

A MANUAL OF PULMONARY TUBERCULOSIS AND AN ATLAS OF THORACIC ROENTGENOLOGY. By David O. N. Lindberg, M.D., F.A.C.P. Springfield, Ill., and Baltimore, Md.: Charles C. Thomas, 1943.

PHYSIOLOGY IN AVIATION. By Chalmers L. Gemmill, B.S., M.D. Springfield, Ill., and Baltimore, Md.: Charles C. Thomas, 1943.